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NUTRIENT CYCLE IN TREE STANDS — NORDIC SYMPOSIUM

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The Nordic working group for forest fertilization is a group of research workers from the Nordic countries Denmark, Finland, Norway and Sweden, which has been working on plant nutrition questions and forest amelioration problems. The group has met annually to discuss current problems, hitherto mostly concerning forest fertilization. In 1976 the question of future working forms came up; the group decided to arrange a symposium on the subject Nutrient cycle in tree stands in 1977.

This symposium took place in Harjavalta and Ikalis in Finland from the 29th of August to 1st of September 1977. During the symposium 12 papers were presented, which are published in the following, either in full or as summaries of a given lecture.

The compilation was made by C. J. Westman.

A BIOELEMENT BUDGET OF AN OLD SCOTS PINE FOREST IN CENTRAL SWEDEN

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1. Introduction

An annual budget of the macroelements in an old Scots pine forest is presented. It is intended to provide data for nutrient models and to be a tool in the identification of interesting problem areas. The aim has been to make the budget as complete as possible. In some parts, especially below-ground, questionable assumptions and data had to be used. The litter and soil are only treated superficially as they are dealt with by STAAF & BERG (1977).

2. Site description

The investigated stand is situated at Jädraås in Central Sweden 60°N, 16°E, 185 m above sea level. The average annual precipitation is 607 mm of which 326 mm falls during the growing season (day temperature > 6° C). The soil is an iron podsol on sandy sediment with a poor nutrient status. The forest is an old Scots pine stand with a well-developed field and bottom layer consisting mainly of *Calluna vulgaris*, *Vaccinium vitis-idaea*, *Pleurozium schreberi* and *Cladonia* sp. There are 393 stems per ha and the stand age is 120—150 years.

3. Data background

Biolement fluxes of all the investigated compartments of the ecosystem as well as increments of branches and stemwood are derived from dry weights and concentrations.

Table 1. Dry weights and bioelements in compartments of the ecosystem ($g\ m^{-2}$).

Compartment	Dry weight	Na	K	Ca	Mg	N	P	S
SCOTS PINE BIOMASS								
Current needles	126.2[1]	.006	.671	.184	.100	1.46	.149	.067
Current shoots	25.7[1]	.001	.133	.038	.021	.26	.036	.012
Older needles	267.5[1]	.016	1.214	.827	.161	3.61	.334	.155
Older shoots	56.0[1]	.003	.265	.158	.044	.39	.048	.025
Branches	810,5[1]	.024	1.013	1.600	.324	2.19	.211	.243
Stemwood	4519.4[1]	.045	1.401	2.440	.633	2.44	.181	.452
Stembark	304.9[1]	.015	.287	1.067	.125	.95	.101	.067
Stump & big roots	1424.2[1]	.010	.926	.555	.171	1.05	.128	.128
Roots 10—50 mm	289.6[2]	.006	.330	.191	.070	.35	.058	.064
Roots < 10 mm	295.0[2]	.021	.490	.307	.136	.53	.112	.118
HEATHER BIOMASS								
Capsules	1.2[3]	.000	.005	.004	.001	.01	.001	.001
Current shoots	38.7[3]	.003	.139	.133	.049	.34	.028	.036
C + 1 shoots	37.2[3]	.004	.107	.109	.036	.31	.022	.036
Older stems	55.8[3]	.004	.088	.075	.022	.27	.022	.036
Roots > 2 mm	127.3[2]	.011	.157	.160	.051	.64	.073	.097
Roots < 2 mm	57.1[2]	.003	.058	.052	.017	.26	.027	.050
COWBERRY BIOMASS								
Current shoots	3.1[3]	.000	.013	.015	.004	.03	.003	.004
C + 1, C + 2 shoots	42.0[3]	.003	.139	.245	.045	.35	.033	.074
Older stems	19.1[3]	.001	.048	.103	.015	.13	.011	.027
Rhizomes	143.3[2]	.019	.239	.233	.058	.89	.111	.171
BOTTOM LAYER								
Mosses	128.3[3]	.022	.560	.310	.078	1.23	.117	.087
Lichens	123.3[3]	.010	.216	.080	.031	.74	.057	.047
BIOMASS TOTALS								
Needles		.022	1.885	1.011	.261	5.07	.483	.222
Tree above-ground		.120	5.906	6.869	1.579	12.35	1.188	1.149
Heather above-ground		.011	.339	.321	.108	.93	.073	.109
Cowberry above-ground		.023	.200	.363	.064	.51	.047	.105
Tree below-ground		.027	.820	.498	.206	.88	.170	.182
Heather below-ground		.014	.215	.212	.068	.90	.100	.147
Cowberry below-ground		.019	.239	.233	.058	.89	.111	.171
Tree		.147	6.726	7.314	1.785	13.23	1.358	1.331
Heather		.025	.554	.533	.176	1.83	.173	.256
Cowberry		.042	.439	.596	.122	1.40	.158	.276
Mosses & lichens		.032	.776	.390	.109	1.97	.174	.134
Total biomass		.246	8.495	8.833	2.192	18.43	1.863	1.863
STANDING DEAD								
Tree branches	57.2[1]	.003	.055	.150	.019	.22	.015	.022
Heather	7.5[3]	.000	.007	.017	.003	.05	.003	.005
Cowberry	1.2[3]	.000	.000	.003	.000	.01	.000	.000
SOIL								
Total surface litter	479[4]	.043	.846	2.140	.257	6.91	.414	.521
Total root litter	216[2]	.014	.264	.306	.097	1.30	.127	.157
Humus layer excl. biomass	1990[4]	.20	1.85	4.57	1.12	16.2	1.07	1.54
Adsorbed		.83	4.58	9.06	1.77	—	—	—
Organic N in the mineral soil		—	—	—	—	78	—	—

1) J. Flower-Ellis (pers. comm.)

2) H. Persson (pers. comm.)

3) H. Persson (1975)

4) H. Staaf (pers. comm.)

Table 2. Bioelement increments in some biomass fractions. Bioelement fluxes in the litter fall and the water flow ($g \cdot m^{-2}$ $year^{-1}$

Fraction	Dry weight	Na	K	Ca	Mg	N	P	S	Cl
INCREMENTS									
Branches & shoots	43.4[1]	.001	.054	.085	.017	.12	.011	.013	
Stemwood	106.1[1]	.001	.033	.057	.015	.06	.004	.011	
LITTER FALL									
Needles	92.9[1]	.007	.071	.330	.035	.38	.025	.041	
Cones	2.5[1]	.000	.003	.001	.001	.01	.001	.001	
Twigs	10.6[1]	.000	.003	.016	.001	.05	.002	.005	
Other	29.2[1]	.001	.027	.102	.012	.09	.010	.006	
Total		.008	.104	.449	.049	.53	.038	.053	
	Water (mm)	Na	K	Ca	Mg	N	P	S	Cl
WATER FLOW 1976									
Incident rain	392	.053	.045	.067	.014	.310	—	.568	.129
Snow fall	117[2]	.024	.013	.019	.004	.048	—	—	—
Throughfall	333	.098	.184	.158	.044	.227	—	.627	.254
at 2 cm[3])	311[4]	.676	.500	.356	.195	.020	—	.798	.967
at 20 cm[3])	220[4]	.648	.136	.230	.079	.013	—	.521	.547

1) J. Flower-Ellis (pers. comm.)

2) Dec. 1975 — April 1976. H. Grip (pers. comm.).

3) The zero level is the border between the humus layer and the mineral soil.

4) P.-E. Jansson (pers. comm.).

Similarly, the fluxes in water flow and litter fall are determined by combining concentrations with quantities of carrier substance. This data basis, which is the origin of all the other derivations except uptake into fine roots, is presented in Tables 1 and 2. The general method for further calculations of fluxes has been to make balances for compartments. To this end a compartment model of the ecosystem has been set up (Figure 1).

The dry weights and water flows of the data basis are contributions from many workers in the Swedish Coniferous Forest Project (cf. Tables 1 and 2). The concentrations used for bioelement contents of biomass and litter fractions are autumn values. Adsorbed cations in the soil are extracted with 1M NH_4Cl. The ecosystem has been delimited at the soil depth of 20 cm from the top of the mineral soil.

Rain and soil water for chemical analysis has been collected every two weeks during the snow-free period in 1976. Incident rain was collected on an open area and throughfall in the 120-year-old stand. The percolating water at 2 cm and 20 cm from the top of the mineral soil was collected in tension lysimeters. Snow on the ground was collected in late March 1976. The quantities of incident rain and throughfall were determined in the above samplings, while quantities of snowfall and percolate in the mineral soil were supplied by hydrologists. The percolation in the soil is estimated from water potential gradients and the unsaturated water conductivity.

The bioelement fluxes in water were determined during one year (1976) while the litter fall is the mean of a four-year period (1973—1976). During the year 1 December 1975—1 December 1976 precipita-

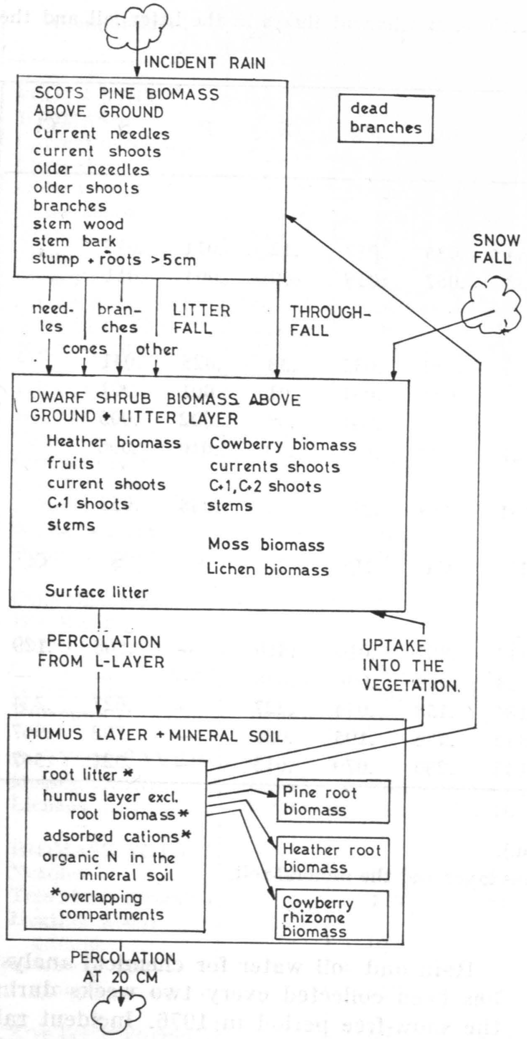

Fig. 1. Compartment model of the forest ecosystem

tion was 501 mm, i.e. less than the mean annual precipitation.

4. Element distribution

Needles have a seasonal variation and fine roots a more irregular variation with time (H. PERSSON 1977). Some fractions of tree biomass have increments. All other compartments of the ecosystem model are regarded as constant during one year.

Roughly 80 % of K, Ca and Mg in the total biomass are present in the trees. Corresponding figures for N, P and S are 70 % and for Na 60 %. Within the trees an especially high proportion of N and Ca is aboveground (94 %), while the other elements apart from Na are up to 87 % aboveground. The pattern in the dwarf shrubs differs from that in the trees.

The amounts of nitrogen and sulphur in the surface and root litter are roughly 40 % of the content in the biomass. Ca and P in the litter are roughly one-third of the biomass and K, Mg one-sixth.

The other stores in the soil are large in relation to the plant biomass. The adsorbed amounts of Ca and Mg correspond approximately to 100 % of the biomass content. The corresponding figure for K is 54 %. The difference can be explained in terms of adsorption and diffusion properties of the cations. The biological activity does not necessarily have to be the reason. Even if the adsorbed amount of Na is small, it is equal to 340 % of the Na in the plants. In this case plant selectivity is probably decisive.

A very large quantity of nitrogen is present in non-available form in organic material in the humus layer and especially in the mineral soil. This amounts to 500 % of the content in the plant biomass. A large proportion of the sulphur out of its ecosystem total is in the FH layer, phosphorus somewhat less. P and S have not been measured in the mineral soil.

5. Input to the ecosystem

The deposition of bioelements with snowfall has been calculated from precipitation quantities for the winter 1975/76 and the concentrations in snow on the ground in late March 1976. At this date a considerable infiltration into the L layer had already taken place. As most of the chemicals in snow are to be found in the first melting water, the concentrations in snowfall have been underestimated.

The input of metals and chloride in the annual precipitation in Central Sweden and Finland is generally reported to be 2–4 times greater than the rain and snow deposition measured in Jädraås during 1976 (STEINHARDT 1973). On the other hand, the 1976 deposition of N and S was twice the common figures for other stations in the region.

It has not been possible to include dry deposition in this bioelement budget. The quantities in dry deposition could well be of the same magnitude as the ones in rain and snow. If dry deposition is added to the ecosystem input, it would affect many of the calculations in the budget, for example the total input-output analysis and the uptake by above-ground components from soil.

6. Uptake from soil by vegetation

Bioelement balances on above-ground fractions of the plant biomass have the general form:

Increment = uptake from soil − litter production − leaching to rain water

The uptake from soil can be calculated if the other terms are known or assumed to be zero. In the case of nitrogen there is uptake from rain water instead of leaching (Table 2). The uptake into the above-ground parts of trees from soil is determined by the following expression:

$$\text{Uptake above-ground} = \text{increment of branches} + \text{increment of stemwood} + \text{increment of stumps} + \text{litter fall} - \text{incident rain} + \text{throughfall}$$

All these terms have been determined except the increment of stumps, which is assumed to be proportional to stemwood increment. The uptake resulting from the calculations is as follows:

	Na	K	Ca	Mg	N	P	S g · m^{-2}year^{-1}
Uptake in above-ground tree biomass from soil	.06	.35	.69	.11	.65	.055	.14

These figures are 5–10 times less than those commonly reported from coniferous stands (KHANNA 1975), which is due to poor soil and old age.

The fraction of the uptake that goes into needles is determinable under the assumptions of zero needle increment and that all interactions between rainwater and the trees take place on the needle surfaces.

$$\text{needle uptake from soil} = \text{needle litter fall} - \text{incident rain} + \text{through-fall}$$

Furthermore, the difference between the contents of the current needles and the uptake into needles is an estimate of the annual translocation from the old needles.

	Na	K	Ca	Mg	N	P	S g · m^{-2}year^{-1}
Needle uptake from soil	.05	.21	.42	.07	.30	.025	.10
Content in current needles ...	.01	.67	.18	.10	1.46	.149	.07
Translocation to current needles ...	−.05	.46	−.24	.03	1.16	.124	−.03

The major part of above-ground uptake is uptake into needles. The translocation values reflect the well-known fact that potassium, nitrogen and phosphorus are withdrawn from aging needles, while Ca, Na and S are not and Mg only to a small extent.

The determinations of uptake into the below-ground parts of the trees are much more uncertain because necessary data is lacking. This deficiency is compensated by assumptions and calculations, which should be interpreted with caution. The uptake fraction of the large roots (1—5 cm) is set proportional to the uptake into branches, which is the sum of branch increment and twig litter fall. The nutrients for fine root formation are probably taken directly from the soil rather than translocated from dying roots. This statement is supported by the concentrations in root litter, which are similar to concentrations of living roots. The fractional uptake of the fine roots is calculated as the dry weight production multiplied by the concentrations. In the calculations from root production no consideration need to be taken of whether there is an increment in this fluctuating biomass fraction.

There is no data on root production from the 120-year-old stand, but an estimation has been made in a nearby 15-year-old stand by repeated samplings of the root biomass (H. Persson, in prep.). This root production has been transferred to the old stand by the following procedure. The biomass of roots < 2 mm has been calculated as the mean of three sampling dates represented in the dry weight records of both stand, the idea being that the seasonal variations should be simultaneous (dry weights supplied by H. Persson). The biomass of the 2—10 mm roots was determined as the mean of all the samplingtime available. The ratio between the biomass and production in the young stand was applied to the old stand, resulting in an estimate of the production and uptake of fine roots in the old stand.

	Na	K	Ca	Mg	N	P	S	g · m^{-2}year^{-1}
Uptake into pine roots from soil								
1—5 cm roots	.00	.02	.012	.004	.03	.004	.005	
< 1 cm roots	.04	.90	.56	.25	.97	.20	.22	
Total uptake by pine	.10	1.27	1.26	.36	1.65	.26	.37	

It is evident that a very large part of the annual uptake is used for fine root production. However, the turnover of fine roots is very fast and the nutrients are rapidly returned to the soil. This bioelement turnover could be regarded as a very local circulation in the soil, which might be overlooked in a large-scale ecosystem budget. However, the internal circulation in the soil is of great interest in nutrient models, which describe processes in a functional way.

To be able to arrive at figures for the above-ground uptake into dwarf shrubs it has been necessary to assume that there is no increment and no leaching by rainwater in this part of the vegetation. The uptake has been set equal to litter production, which has been estimated by Staaf using information in the literature (Staaf & Berg 1977). The uptake into the fine roots of *Calluna* and the rhizomes of *Vaccinium vitis-idaea* is calculated from dry weight production in the 15-year-old stand using the same procedure as for pine roots (data from H. Persson).

	Na	K	Ca	Mg	N	P	S	g · m^{-2}year^{-1}
Uptake into heather shoots	.00	.02	.04	.006	.12	.007	.006	
Uptake into cowberry above-ground	.00	.003	.02	.001	.05	.002	.005	
Uptake into heather roots	.002	.04	.04	.01	.17	.02	.03	
Uptake into cowberry rhizomes	.03	.35	.35	.09	1.31	.17	.25	

The most striking of these figures are the ones for uptake into cowberry rhizomes. The combination of concentrations and rhizome production is made under the assumption of no translocation from old rhizomes. The high concentrations in rhizome litter justify this assumption.

7. Input/output analysis

For the total forest system an input-output analysis should have the form:

$$\text{Incident rain} + \text{snow fall} + \text{dry deposition} - \text{percolation at 20 cm} = \text{increment}$$

In this case dry deposition is unknown and therefore ignored. The input-output balance of the tree stratum above-ground is the sum of increments in branches, stemwood and stumps.

For the system [soil + L layer + field vegetation] the following balance has been used:

$$\text{Throughfall} + \text{snow fall} + \text{pine litter fall} - \text{percolation 20 cm} - \text{uptake above ground by trees} = \text{increment}$$

The sum of the tree stratum and the latter stratum should equal the ecosystem balance, which is a check that the calculations of above-ground uptake have been correctly performed. A further separation into litter layer and humus layer has been made by Staaf & Berg (1977) in budgets emanating from the mineralisation process.

	Na	K	Ca	Mg	N	P	S	Cl	g · m^{-2}year^{-1}
Total ecosystem	−.57	−.08	−.14	−.06	.35	—	.05	−.42	
Tree stratum	.002	.11	.16	.04	.21	.02	.03	—	
Soil + L layer + field vegetation	−.57	−.19	−.30	−.10	.15	−.01	.02	—	

The negative metal balances on the [soil + L layer + field vegetation] are due to weathering in the mineral soil. The order of the decrease is Na > Ca > K > Mg. The order of occurrence in the minerals of the local soil is K > Na > Ca > Mg. The different position of K in the two sequences is probably due to withholding in the intensive internal circulation of the soil (Table 3, ratio b) rather than a difference in the weathering rates. The negative balance of chloride points to a Cl source inside the ecosystem which is difficult to explain, while sulphur has an input which almost aquals the output in the tree stratum and the soil.

Nitrogen has positive increment in the stratum of [soil + L layer + field vegetation]. The accumulation takes place in dead and living organic material. The nitrogen fixation in the 120-yearold stand has been estimated to be 0.0347 g N·m^{-2}·yr^{-1} (Granhall & Lindberg 1977), which should be added to the soil balance for nitrogen.

8. Features of the bioelement circulation

The variables that will be discussed under this heading are all ratios between quantities of one bioelement. This means that they are suitable for comparisons between the different elements.

The first ratios (Table 3, ratio a) are intended to compare the internal circulation in the tree stratum with effluxes from the ecosystem. The uptake is considered a better estimate of the internal cycle than [litter fall + throughfall] as tree increments are

Table 3. Some bioelement flux ratios.

Ratio	Na	K	Ca	Mg	N	P	S
a. (uptake above ground by trees)/(percolation at 20 cm)	.084	2.6	3.0	1.4	50		.27
b. (total uptake by trees and dwarf shrubs)/(percolation at 20 cm)	.19	12	7.4	6.0	254		1.3
c. (tree litter fall)/(throughfall)	.092	.56	2.8	1.1	2.3		.084
d. (total heather uptake)/(total pine uptake)	.02	.043	.057	.047	.18	.096	.11
e. (total cowberry uptake)/(total pine uptake)	.30	.28	.29	.25	.82	.64	.71
f. (moss uptake)/(total pine uptake)	.05	.077	.064	.047	.18	.096	.086

included and incident rain excluded. The ratios show that nitrogen has a very closed cycle in the forest, while those of K, Ca, Mg and S are more open. Phosphorus has a very closed internal cycle, although there are no measurements of efflux in this case. Na has very little cycling in the ecosystem. The features described become even more evident when cycling in the belowground portions of the plant biomass is taken into account (ratio b). Still further internal circulation occurs in the form of uptake and release by microorganisms. The causes of tightness in a cycle in the forest are the uptake efficiency of the vegetation, the holding capacity of the soil and the resistance to breakdown in the litter.

Downward transport through the forest are divided into two main pathways in the above-ground stratum, i.e. water throughfall and litter fall. In the upper part of the soil there is a similar division on water and organic material being the carrier substance (Staaf & Berg 1977). The divalent cations are more associated with the litter fall than the monovalent cations and sulphur (Table 3, ratio c). For Na, K and N there is a connection between the proportions in litter fall and the tightness of the cycles.

The ratios between the uptakes into different plant species (ratios d, e and f) show that the dwarf shrubs are taking a large share of especially N, P and S. The unexpected figures for cowberry should be treated with caution. The uptake into mosses, which has been set equal to moss litter production estimated by Staaf & Berg (1977), is rather large for N and P. The moss carpet is drawing its nutrients almost entirely from rain water (C. O. Tamm 1953) and is not competing with the trees belowground. The elements in the throughfall are withheld for some time on their way into the soil.

The turnover time is the time for complete renewal of a bioelement in a compartment. It is estimated by dividing the compartment size with the flux through the compartment Of course, this does not necessarily mean that all the compartment content has actually been renewed during the turnover time calculated in this way as there may be more or less convertible fractions inside the compartment. Compartmentalisation should be performed in a way whereby the turnover concept makes sense. For example, the turnover time in the above-ground tree biomass is an obscure mean value between the turnover times in needles and in boles, the latter having infinite turnover time as long as tree death is not taken into account.

The turnover times in needles are in the order P > N > K > Mg > Ca > S > Na (Table 4). There is a connection between the tightness of the internal cycle above-ground, except for Ca and S. The turnover times for N, P and K are longer than the age of the oldest needles as a result of translocation.

Table 4. Turnover times for bioelements in biomass fractions (years).

Bioelement	Na	K	Ca	Mg	N	P	S
(needle biomass)/(needle litter fall + throughfall)	.21	7.4	2.1	3.3	8.3	19	.33
(live shoots and branches)/(twig litter fall)	90	500	110	400	50	150	60
(pine biomass below ground)/(pine uptake below ground)	1.4	1.1	1.2	1.2	1.1	1.2	1.2
(live dwarf shrubs below ground)/(dwarf shrub uptake below ground)	1.1	1.2	1.2	1.3	1.2	1.2	1.1

The turnover times in shoots and branches are very approximate because of the small fluxes in twig litter fall and the increment in the compartment. The application of the above calculation method on an increasing compartment is not quite correct. The time for complete renewal is underestimated. However, the figures reveal very long turnover times, in some cases longer than the entire age of the stand. The relative order of the elements is K > Mg > P > Ca > Na > S > N. In comparison with the situation in needles, N and to some extent P have faster turnover times in relation to the metals.

The turnover times for the below-ground parts of pine and dwarf shrubs are all about one year. If pine roots < 1 cm had been considered separately the turnover would have been even faster. The uptake into below-ground parts has been determined as certain proportions of the root dry weights, hence the similarities between the different bioelements. However, the turnover times for pine roots and dwarf shrub roots are independently determined.

10. Literature

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MOBILIZATION OF PLANT NUTRIENTS IN A SCOTS PINE FOREST MOR IN CENTRAL SWEDEN

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1. Introduction

The release of nutrients from litter and humus is a fundamental process in the internal biogeochemical cycle of an ecosystem. Forests are known to recycle plant nutrients very efficiently (SPURR & BARNES 1973). The mechanism for mobilization of nutrients from dead organic matter in soil and litter are at present by no means fully understood. Three main processes appear to be:

- Mineralization by soil organisms, i.e. enzymatic breakage of covalent bonds in organic molecules resulting in inorganic forms.
- Biological or physical breakdown of organic matter liberating structurally enclosed but not covalently bound elements to a water-dissolved or exchangeable form.
- Ion exchange of adsorbed inorganic nutrients.

The mobilized elements can be transported in the water phase by mass flow (leaching) or diffusion out of the studied system or be absorbed onto soil particles, fixed in minerals, precipitated as salts, or immobilized by microorganisms or plant roots. In general it is possible to study only net results of many such processes during a certain period of time with different non-continuous measurements. The problems connected with the practical studies are several; one, for example, is the difficulty in determining the chemical status of bioelements in different soil fractions and to evaluate their availability to microorganisms and plants, another is to define structural boundaries of the system suitable from both a practical and relevant point of view.

The present paper reports on work in progress on decomposition and mineralization within the Swedish Coniferous Forest Project (SWECON) and has the following aims:

- To describe changes in amounts of nitrogen, phosphorus, potassium calcium and magnesium in decomposing needle litter in a mature Scots pine forest in Central Sweden.
- To present a nutrient budget for the mor with emphasis on the amounts of nitrogen, phosphorus, potassium, calcium and magnesium mobilized annually from the L and FH layers.

2. Site description

The 120–130-year-old Scots pine stand studied is located at the SWECON research site, Ivantjärnsheden, Central Sweden (60° 49′N, 16° 30′E) at an altitude of 185 m on a flat area of deep glacifluvial sand sediments. The mean annual precipitation in a nearby village is 609 mm (1931–60), and the mean annual temperature +3.8° C. The length of the vegetation period is about 160 days.

The tree layer is exclusively composed of *Pinus silvestris* and has a density of 393 trees per ha and a height of 17–19 m. *Calluna vulgaris* and *Vaccinium vitis-idaea* form a well-developed field layer, and the bottom layer, completely covering the ground, is mainly composed of the mosses *Pleurozium schreberi* and *Dicranum rugosum* together with *Cladonia* lichens.

The most recent direct effect of forestry practices is a slight thinning in 1960. Further details on vegetation and stand history are given by BRÅKENHIELM (1975).

The soil profile is an iron podsol with a weakly developed bleached horizon (2–7 cm) and the humus type is a typical mor. A very loose litter layer (A_{00}), with living mosses and lichens interwoven in it, covers a humus layer ($A_{01}-A_{02}$) of 5–10 cm. The A_{01} (F) and A_{02} (H) horizons are almost indistinguishable from each other. The pH range is 3.9–4.2 in the humus layer and 4.6–4.8 in the upper mineral soil. The parent mineral material as well as the whole soil is considered as very poor in essential nutrients (BRINGMARK & PETERSSON 1975).

3. General assumptions

The following assumptions were considered to have an approximate validity in the mor of the stand studied. They were used in calculations and in the construction of the nutrient budget:

- The mor layer is in a dynamic steady state condition, seen on a oneyear basis, as regards amounts of organic matter and nutrients in the whole layer as well as in its major components.
- Nutrients are transported out of the FH layer exclusively in an inorganic form in the soil water phase.
- Nutrient uptake by roots occurs only in the FH layer.

4. Materials and methods

4. 1. Static chemical description of the mor

On 4 September 1975 quantitative sampling of the L and FH and FH layers took place on 24 circular plots, each of 700 cm², in a randomized block of 200 × 100 m within the stand. The litter samples were sorted into needles, bark, cones, pine twigs < 5 mm ø and > 5 mm ø, heather litter, moss litter, cowberry leaves and a miscellaneous fraction. The FH samples were not subdivided in different structural components, but roots and stem parts and attached dead parts were removed.

All samples were weighed individually after drying at 85° C and pooled to form five composite samples. They were analyzed for total content of carbon, nitrogen, phosphorus, potassium, calcium, magnesium and ash. Areal amounts of nutrients in the different litter and soil components were subsequently calculated. The concentrations of nutrients in the humus layer were expressed on an ashfree basis.

4. 2. Mobilization of nutrients from litter

4. 2. 1 Needle litter

In October 1973 needles of the oldest generation were collected at litter fall from the branches of about 15-year – old trees just outside the stand. Their chemical composition was almost identical with litter fall needles in the stand. The needles were dried at room temperature to a moisture content of 5–6 %, put into nylon bags with a mesh size of 1 mm, and placed in the field in early May 1974.

Three times a year a set of twenty litter bags was sampled; in May, August-September and October. The weight loss was determined after drying to constant weight at 85° C and composite samples from each sampling were analyzed for total carbon, nitrogen, phosphorus, potassium, calcium and magnesium. Net changes of elements in the decomposing needle litter were then calculated.

The mean annual decomposition rate was taken as a mean value for the three years of study, and used together with data of litter input and soil litter amounts to calculate the mean residence time of needles in the litter components as defined here. Litter fall was generalized to occur in April (10 g/m²) and in September (83 g/m²) and the remaining weights of such litter falls in September of a certain year were calculated, in a time sequence, and accumulated until the litter box was filled up.

All needles of one litter fall were considered to leave the litter box instantaneously at a certain degree of decomposition and turn into humus. The age of the oldest unit will then represent the mean age of needles leaving the litter component. The remaining amounts of elements in the litter after that period of decomposition were read from the results of the litter bag measurements and used to calculate annual amounts leaving needle litter in mobilized and non-mobilized form.

4. 2. 2 Other litter

Other L layer litter types than needles

were treated together as one functional unit. The same relation as for needles between mobilized and non-mobilized nutrients leaving the litter was used. The amounts transferred out of this unit litter were quantified on the basis of the steady state concept.

4. 3. Mobilization of nutrients from humus

The miscellaneous fraction of the L layer was classified as humus with regard to its structural appearance. Its chemical composition was found to be more similar to that of the FH layer humus than to that of the litter (STAAF & BERG 1977). No decomposition studies were carried out on this component and its function in the model is only to store nutrients, and no net mobilization of elements is assumed to occur from it.

Additions to the FH layer humus will thus comprise input from the L layer and root litter formation; losses are transport into the mineral soil and net immobilization in living roots. Due to the practical difficulties in separating root litter from humus, the root litter formed is treated as humus in the budget.

The amounts of plant nutrients mobilized on a yearly basis and the amounts taken up by plant roots were taken from a static influx — outflux budget where these two quantities were obtained as differences.

4. 4. Gains and losses of the system

Data on annual influxes of elements by wet deposition, litter fall from pines, and water transport out from the L and FH layers was taken from BRINGMARK (1977).

Table 1. Amounts of elements in soil structures and measured fluxes of nutrients in the mor of the mature pine stand. For further details see the text.

Soil layer	I. COMPONENTS	Weight (g/m²)	Amounts of nutrients (mg/m²) N	P	K	Ca	Mg
L	Needle litter	150	1290	80	130	510	50
	Other litter[1])	310	2500	150	420	920	98
	Humus	210	3120	180	290	710	110
FH	Humus[2])	1540	16200	1070	1850	4510	1120
	II. INFLUXES	(g/m²/yr)	(mg/m²/yr)				
L	Needle litter	93	380	25	70	330	35
	Other litter	98	240	46	150	250	40
	Through fall		280	<10	200	8	48
FH	Root litter	250	1470	190	430	820	140
	Soil water		190	≈5	680	710	160
	III. OUTFLUXES	(g/m²/yr)	(mg/m²/yr)				
L	Soil water		190	≈5	680	710	160
FH	Soil water		20	<3	500	360	200

[1]) Includes bark, pine twigs, cones, heather litter, cowberry leaves, and moss litter.

[2]) Total layer except living roots and attached dead.

[3]) Includes snow.

Above-ground litter formation from heather was calculated from the relation litter production/biomass as determined in heather stands of the same development phase (CORMACK & GIMINGHAM 1964) and biomass figures from the present stand (PERSSON 1975). The litter input was multiplied by element concentration figures for attached dead material. The corresponding data for cowberry leaves were calculated from biomass data (PERSSON 1975) and concentrations of nutrients in attached dead material.

Inputs from moss litter formation were obtained from the assumption of an annual turnover of 1/4 of the biomass (STJERNQUIST pers. comm.) and nutrients concentration in attached dead material from the stand.

Input to humus by root litter formation was given by PERSSON (pers. comm.). and based on the relationship between litter formation and biomass from heather covered parts of an 18-year-old pine stand situated close to the old one. This data was then transformed to the corresponding soil layer in the old stand with biomass data available from three samplings in 1974—75 (PERSSON pers. comm.), and multiplied by values on nutrient concentrations in root litter.

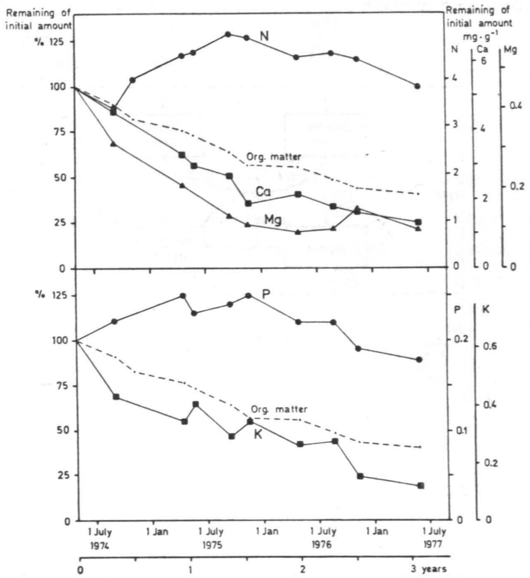


Figure 1. Amounts of nutrients in decomposing needle litter. The dashed line showing organic matter weight loss in litter bags is the same in both graphs. The measurement was started in May 1974.

5. Results and discussion

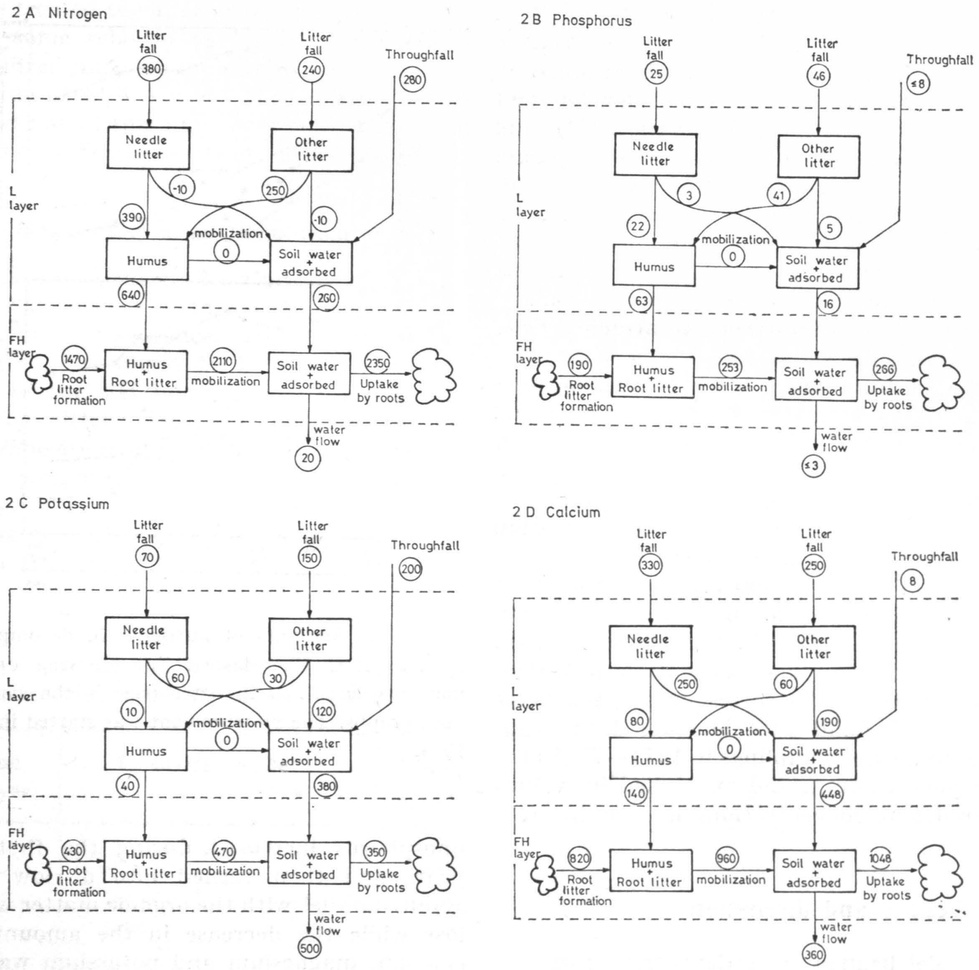
5. 1. Mobilization of nutrients from litter

5. 1. 1 Needle litter

The mean annual weight loss value of 26 % gave a mean residence time for the needle litter component in the L layer of 2.8 years. The litter component determination had an accuracy of ± 15 % (95 % CL) which gave an interval between 2.4 and 3.4 years. A probable systematic underestimation in the assortment procedure makes a figure of three years reasonable for the mean residence time of needles in the litter component. After a period of this length the needle litter contained 103, 89, 19, 25 and 22 % of their initial amounts of nitrogen, phosphorus, potassium, calcium and magnesium respectively.

Two types of nutrient loss regimes in decomposing needle litter were found (Figure 1). The absolute amounts of nitrogen and phosphorus increased during the first 1.5 years and then turned into a slow loss, about parallel with the organic matter weght loss while the decrease in the amounts of calcium, magnesium and potassium was almost parallel with decomposition from the start.

The nitrogen and phosphorus contents in the needle litter unit increased to a maximum of about 130 % of the inital amounts, representing net import of 370 mg N/m² and 20 mg P/m² during the approximately 1.5 years of accumulation. The simultaneous and equal effect on nitrogen and phosphorus makes a biological mechanism probable — such as translocation by fungal hyphae. The first year requirement of 250 mg N/m² and 20 mg P/m² can be explained for nitrogen but not for phosphorus by the amounts added in the throughfall. A potential source of these elements is mineralized nutrients from older litter generations that, together with wet deposited amounts, would fill the needs of all types of litter except for a small shortage of nitrogen. This recycle mechanism



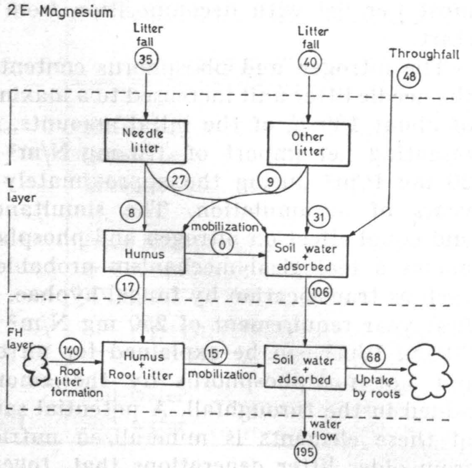


Figure 2 A-E. Budgets for N, P, K, Ca and Mg in the L and FH layers of the mor layer in a 120—130-year-old Scots pine stand in Central Sweden. The budgets are constructed with both measured and calculated flux data. For details see the text. All values are in mg/m^2/year.

is proposed to be operating within the present mor layer. The total effect for the L layer is a small net immobilization of nitrogen but a mobilization of phosphorus (Figure 2A—B).

The C/N and C/P ratios of the decomposing needle litter changed from initially 134 and 2560 to relatively constant values of about 60 and 1200 respectively (Table 2). This threshold point coincided in both cases with the change from a net gain to a net loss of these elements from the structure. This behaviour indicates that either nitrogen or phosphorus or both were limiting for decomposition during the initial phase.

Table 2. Weight loss of decomposing needle litter and carbon/element ratios in a mature Scots pine stand, Central Sweden.

Date	Days of decomposition	Weight loss (% of initial weight) $\overline{X}$	SD	C/N	C/P	C/K	C/Ca	C/Mg
740502	0	0		134	2560	824	99	1140
740902	123	10.4	1.0	140	2180	1090	105	1490
741103	185	17.8	3.9	129	n.d.1)	n.d.1)	n.d.1)	n.d.1)
750411	344	24.4	4.4	85	1520	1120	116	2396
750513	376	27.3	5.0	85	1690	950	128	2620
750904	490	35.7	4.0	68	1380	1150	126	2600
751029	545	43.2	4.6	60	1120	870	155	2710
760428	726	44.4	3.6	66	1330	1130	135	3250
760825	845	51.2	5.4	57	1130	930	146	2480
761110	922	55.8	5.2	53	1210	1530	146	1530
770601	1125	58.8	7.2	57	1210	1860	164	2170

1) n.d. = not determined

For potassium and magnesium the heavy losses occurred during the first four months, which might be mainly due to leaching as both elements are relatively easily leached from plant litter (Turkey 1970). Potassium is present in plant residues as water soluble salts (Alexander 1961) and can thus be mobilized without microbial activity, while magnesium is partly bound in organic components by covalent bonds and consequently this organic part must be mineralized before being leached out in ion form. Gosz *et al.* (1973) report a critical C/Mg ratio of 900—1350 above which no net release from leaf litter occurred. This observation does not appear valid in this case as the ratio, starting from 1140, passed 1500 already after four months and then steadily rose to 2200 (Table 2).

Calcium is present in ion form in living and dead plant parts but is firmly enclosed in cell wall structures swhich makes it rather immobile (Gosz *et al.* 1973). The fact that cell wall constituents make up a major part of coniferous litter (Millar 1974) explains why calcium is lost from needle litter at a rate more related to organic matter weight loss than potassium and magnesium. Calcium is not mineralized, and as also in the cases of potassium and magnesium, the microorganisms only have an indirect role in its mobilization.

5. 1. 2 Other litter

No data from direct measurements is available and the conclusions drawn are thus founded on estimated values. The »other litter» appears to have a lower decomposition rate than needles as judged from its apparent turnover time (stored litter/litter input) — 3.2 years compared to 1.6 for needle litter. This is reasonable as the annual decomposition rates for e.g. moss, bark and twig litter were found to be only 18, 11 and 5 % respectively but 26 % for needles. Still, its contribution to the input of elements to the litter layer is considerable — especially for phosphorus and potassium.

5. 2. Mobilization of nutrients from humus

Apart from living roots with attached dead material, and occasional cones and twigs, a structural division of the FH layer humus was very difficult to perform. Decomposition and humification are continuous processes and any attempt to compartmentalize them must be more or less arbitrary. It is therefore impossible to state how much of the nutrients has been mobilized from the humus component of the FH layer: it depends on how strict a definition is used.

The identifiable root litter in the FH layer is about 150 g/m² (Persson pers. comm.) and the yearly weight loss for pine roots (1–2 mm diameter) was about 26 %. The fact that the yearly root litter input was 250 g/m² means that they stayed in this compartment for about one year and after that they could be considered as humus.

The C/N and C/P quotients of the humus and its sources give rise to the following discussion: If the two inputs to the FH layer humus, namely root litter and L layer humus, were mixed according to their relative inputs to the FH layer (that is 8: 3) a C/N ratio of 74 would be achieved which indicates a considerable incorporation of nitrogen into the humus during decomposition. The change in nitrogen content in decomposing litter made it appear unreasonable that a major part of the 1470 mg N/m² which is brought into the root litter compartment (Fig. 2A) should be mineralized in one year. Thus it seems safe to conclude that the main part of the 2112 mg N/m² annually mineralized from root litter and humus (Fig. 2A) would come from humus as defined here. From the C/P ratio of humus it is clear that, on average, the humus had a higher loss rate for phosphorus than for weight. This means that with a calculated mean annual turnover of 16 % of the humus a minimum amount of 171 mg of phosphorus was mineralized annually, which should be compared with the figure of 217 mg for the total humus and root litter component. Therefore practically all of the phosphorus mineralized must come from humus.

In a structurally fragmented humus most of its potassium, calcium and magnesium is in an adsorbed form (Bringmark & Petersson 1975) which has the potential for removal by ion exchange or chelate formation (Ca Mg) mechanisms. These must be the most important mobilizing processes for these elements in humus (cf. e.g. pp. 211–213 in Scheffer & Ulrich 1960) and will not be dealt with further here.

5. 3. Nutrient budget and conclusions

Annual net fluxes of nutrients in the mor layer are given in figures 2A–E. In several cases no statistical calculation of errors has been possible, and the resulting estimates of quantities are accordingly uncertain. Despite this it should be feasible to set up some features of general behaviour of the nutrients in the system. A comparison of estimated nutrient uptake by roots in the FH layer calculated from our nutrient budget and that in the total soil horizon, the latter figures taken from Bringmark (1977) gives:

	N	P	K	Ca	Mg
Total root uptake (mg/m²yr)	3300	460	1700	1300	460
Root uptake in FH layer (mg/m²/yr) ...	2400	270	350	1000	70

Nitrogen and phosphorus are both mainly recycled to plants in the FH layer. The elements are strongly retained in the organic material of the L layer, and mineralized mainly from humus in the FH layer. For nitrogen, canopy drip is an important source for the L layer, and net immobilization might occur here.

Calcium is taken up by plants mainly in the FH layer, but the mobilizing processes take place in both layers – preferably from litter. Transport to the mineral soil are much more extensive than for nitrogen and phosphorus.

Potassium and magnesium fluxes appear to be very similar; these nutrients tend to be more easily mobilized from litter than the other elements and thus more coupled to the water phase. A large part of the annual influxes leave the mor for the mineral soil, and only a minor part of the total uptake in plants occurs in the mor.

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ACCUMULATION OF ORGANIC MATTER AND NITROGEN ON SAND DUNES FOLLOWING SAND FIXATION AND PLANTING OF DWARF MOUNTAIN PINE

(*Pinus mugo* var. *mughus* (Scop.) Zenari).

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Summary of given lecture:

The primary purpose of the work presented was to investigate the ability of a single tree species *(Pinus mugo var. mughus)* to accumulate, in the course of time, organic matter and nitrogen in the soil under unthinned, closed stands, planted in soils extremely poor in humus and nutrients (dune sand).

Concurrently, a number of characteristic stand and soil factors have been investigated and put in relation to the stand age.

Calculations of the accumulated organic matter and nitrogen in the mountain pine stands have been used in working out estimates of the accumulation of these factors in the total vegetation/soil system.

The research material consists of stand data and soil samples collected in 1966–67 from 18 sample plots located in unplanted and mountain pine planted dunes (Stand ages from 21 to 112 years) about 1–7 km from the west coast of Jutland. The sample plots are situated within an area covering a distance from north to south of about 75 km, from 55° 46' to 55° 06' northern latitude.

The present investigation proves that after planting white dunes with mountain pine, accumulation of organic matter and nitrogen in the total vegetation/soil system takes place as a result of individual accumulation processes in the stand and soil.

Thus, in the stand annual accumulation is calculated to culminate already before the age of 10 years with about 1360 kg organic matter and 4.6 kg N per hectare. Thereafter the annual accumulation falls, 100–110 years after planting amounting to 170 kg organic matter and 0.4 kg N per hectare.

In the total soil layer a maximum accumulation of well over 900 kg organic matter

and about 12 kg N per hectare per year seems to be reached, respectively, 25–30 and 15–20 years after planting, but as a result of continued reduction in the reserves of the mineral soil starting from about the same time, a fall in the total annual accumulation then commences. For the organic matter and N, 60 and 80 years respectively after planting, this fall changes into a direct reduction of the so-far accumulated reserves, resulting in an annual loss of the order of 870 kg organic matter and 11 kg N per hectare 100–110 years after planting.

The total result of these sub-processes is the accumulation and reduction processes for the total vegetation/soil system shown in Figure 1.

As might be expected from a tree species of so low a productivity as mountain pine planted in an initial substratum so poor in nutrients as the west-Jutland dune sand, total accumulation in the vegetation/soil system of max. 14 kg N/hectare/year is nearly the minimum of what has been recorded for more productive tree species planted in more fertile soils. Thus, Richards (1964) reports from England average accumulations in and below about 20-year-old conifer stands of, for the majority, between 22 and 85 kg N/hectar/year. A few larger (136 and 153 kg N) and smaller (3.6 kg N) accumulations have been, possibly defectively, recorded. Early build-up of organic matter and N in the soil under pioneer stands on an originally raw mineral soil, followed by a fall in the built-up reserves, has earlier been demonstrated in melted glacier areas in Alaska (Crocker and Major 1955). Here the reduction of the N-reserves were however, associated with the natural replacement of an N-binding alder stand *(Alnus crispa)* by a non N-binding spruce stand. The absence of investigations of accumulation in the stands prevented an estimate of whether the N that had disappeared from the soil could be found there.

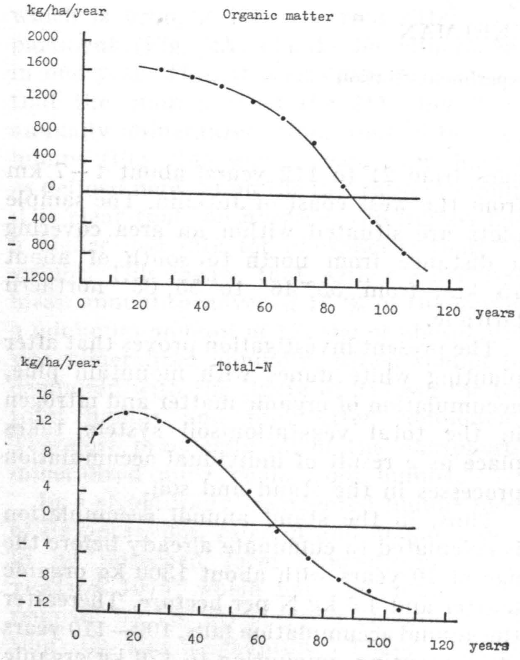

Fig. 1. Average annual accumulation of organic matter (y) and total N (z) in soil + stand as a function of stand age (t).

The present investigation shows, however, that reduction of early accumulated reserves of organic matter and N in the soil may also take place without any such special change in tree species, and this therefore is perhaps a more general feature in the soil formation which takes place under pioneer stands as a function of the vegetation development and the time.

Losses from a total vegetation/soil system, dominated by a single tree species, corresponding to a reduction of the quantities of organic matter and N accumulated in the system during the first 50–75 % of the normal life time of the stand, plus the current supply of these factors from the surroundings of the ecosystem, especially the atmosphere, do not seem to have been earlier rendered probable or recorded.

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SAMBANDET MELLAN TORVMARKSTYP OCH YTTORVENS NÄRINGSHALTER

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Abstrakt

Torvmarksforskningen i Finland har som väl känt är, uppnått vördnadsvärda proportioner. Merparten av denna forskning har inriktats dels på en reglering av torvmarkernas vattenhushållning, vilket är av primärt intresse då en vattendränkt torvmark tas i bruk för skogliga ändamål och dels på att klarlägga de mera eller mindre trädbevuxna torvmarkernas potentiella virkesproduktionsförmåga. Jämfört med de nämnda forskningsriktningarna har torvmarkernas näringsbalans relativt sett erhållit ett mindre intresse på sin del. Talrika och omfattande gödslingsförsök har anställts (Peatland . . .), men av någon anledning har grundforskningen inom detta område blivit åsidosatt. Eventuellt har tron på den Cajanderska torvmarksklassificeringens förträfflighet tillsammans med de lovade resultaten av träaskegödslingsförsök i såväl i Finland som Sverige haft en bidragande orsak till utvecklingen. Så sent som år 1974 började man i Finland allmänt dryfta frågan om tillväxtstörningar i lovande plantskogsbestånd, vilka abnormiteter antogs beroa av ett näringsämnesunderskott i torven (Huikari 1974). Diskussionen gällde då närmast brister på mikronäringsämnen, men vissa forskningar tyder på avvikelser även efter gödslingar med makronäringsämnen. Det finns sålunda ett klart behov av en forskningssatsning för att klarlägga torvmarkernas näringsstatus. Det finländska skogsbruket indelar torvmarkerna enligt ett fytosociologiskt system i torvmarkstyper (Cajander 1913, Lukkala 1929, Lukkala och Kotilainen 1945 samt Heikurainen 1968), vilka på ett tillfredsställande sätt anger de olika växtplatsernas potentiella förmåga till virkesproduktion efter en skogsdikning (Lukkala och Kotilainen l.c., Heikurainen 1959 samt Seppälä 1969). I praktiken fungerar klassificeringssystemet på ett tillfredsställande sätt. Teoretiskt blir dock frågan om vilka faktorer i torven som avspeglas i ytvegetationen av avsevärt intresse. Det är klart att en mängd olika faktorer i samspel bestämmer sammansättningen av torvmarkernas växtsamhällen. Heikurainen (1972) har dock ansett, att det i huvudsak är två gradienter som styr utvecklingen, en hydrologisk och en markkemisk gradient. Detta granskningssätt ger till resultat, att den markkemiska gradienten efter en skogsdikning i mycket hög grad bör inverka på beståndstillväxten då, åtminstone teoretiskt sett, den hydrologiska gradienten har optimerats. Följaktligen blir yttorvens näringshalter av speciellt intresse om man strävar till en total optimering av virkesproduktionen på dikade torvmarker. Yttorvens betydelse understryks av att merparten av trädens rötter såväl före som efter en skogsdikning befinner sig i det allra översta torvskiktet (Heikurainen 1955 och Paavilainen 1968).

Vahtera (1955) har undersökt yttorvens kemiska egenskaper på 50 år gamla och yngre skogsdikade torvmarksområden. Det framgår, att det råder ett någorlunda gott samband mellan skogsdikningsbonitet, d.v.s. torvmarkens virkeproduktions förmåga, och yttorvens surhetsgrad, halt av totalkväve samt halt av kalcium. En klassificering av torvmarkerna med hjälp av markkemiska variabler visade sig dock förenad med svårigheter och resulterade i avvikelser från det boniteringssystem som föreslagits av Lukkala och Kotilainen (l.c.). Senare har Holmen (1964) och Haveraeen (1969) rapporterat i stort sett jämförbara resultat angående sambandet mellan ytvegetation och markkemiska variabler. Valk (1973) konstaterar att yttorvens näringshalt inte är någon tillförlitlig faktor då det gäller sambandet mellan yttorv och ytvegetation. Näringshalterna kan variera avsevärt under likartade växtsamhällen. De ovannämnda resultaten har avsett totala växtnäringsämnen; om man undersöker lösliga närings-

ämnesfraktioner i torven blir bilden sannolikt mera komplicerad. Holmen (l.c.) noterar en tendens till negativ korrelation mellan beståndskarakteristika och ammoniumlaktatlöslig fosfor och kalium. Mannerkoski (1973) kunde å andra sidan påvisa en positiv korrelation mellan torvens halt av ammoniumacetatlösligt kalium och kunde även med hjälp av markanalyser fastslå behovet av en kaliumtillförsel. Paarlahti m.fl. (1971) konstaterar att markanalyser, såväl extraktion med surt ammoniumacetat som het 2-n saltsyra, förklarar föga av beståndstillväxten efter en skogsdikning. Diskrepanserna mellan resultat av markanalyser och beståndsdata får förklaras med flera olika teorier. För det första bör man notera att det taxonomiska begreppet torvmarkstyp är ett uttryck för samspelet mellan ett flertal olika växtfaktorer och att den tidigare nämnda uppdelningen på två gradienter i detta hänseende får anses som synnerligen generaliserande. Samspelet mellan bottenvegetationen och ett s.a.s. på konstlad väg skapat trädbestånd är eventuellt inte det bästa; bottenvegetationen kan i vissa fall vara den starkare parten i kampen om näringsämnena, vilket kan antas vara fallet på t.ex. risdominerade torvmarker (j.fr. Sarasto och Seppälä 1977). Också vid skogsgödsling binds en betydande del av de tillförda näringsämnena i bottenvegetationen (Haveraaen 1967 och Paavilainen 1973). Vidare bör man isynnerhet om man arbetar med lösliga näringsämnesfraktioner beakta att sambandet mellan vad man kan kalla ögonblickliga analysvärden och beståndstillväxten under en lång utvecklingsperiod inte behöver vara det bästa. En interaktion mellan metallkationerna i torven får dessutom antas förekomma då dessa till en hög grad föreligger i mera eller mindre utbytbart tillstånd. Sålunda sjunker t.ex. torvens kaliumhalt med stigande kalsiumhalt då kalsium som en tvåvärd kation har en större bindningsenergi.

Försöksuppläggning och material

De forskningsresultat som har citerats tyder på svårigheter då man söker använda markkemiska variabler för en optimering av virkesproduktion på dikade torvmarker. Trots att det finns en mängd uppgifter om ett flertal olika torvmarkers näringsstatus är bilden inte enhetlig. Eventuellt är det just denna forskningsobjektens stora spridning som resulterat i denna heterogenitet. En möjlighet att övervinna denna heterogenitet erbjuds måhända av teorin om de kontinuma växtsamhällesserierna vilka på ett förenklat sätt framställts av Heikurainen (1972) mot bakgrunden av det tidigare nämnda tvågradientsystemet. Genom att välja en avgränsad serie närbesläktade växtsamhällen, vilkas genomsnittliga potentiella virkesproduktion är känd, kan man eventuellt finna ett samband mellan yttorvens näringshalter, ytvegetationen och därmed virkesproduktionsförmågan. En sådan för ändamålet lämplig serie är de tallmyrar vilka karakteriseras av en bottenvegetation bestående av halvgräs och gräs med inslag av antingen ris eller örter. Enligt finländska begrepp skulle i denna serie ingå följande torvmarkstyper (växtsamhällen): lågstarrmyr, egentlig starrmyr och örtrik starrmyr samt några undervarianter av desamma. Dessa växtsamhällen uppvisar en synnerligen prydlig stigande potentiell virkesproduktionsförmåga.

I det följande kommer i korthet att redogöras för endel preliminära resultat av en undersökning, vilkens målsättning är att utröna om det råder ett samband mellan yttorvens näringshalter och ytvegetationen och därmed den potentiella virkesproduktionsförmågan på de nämnda starrmyrarna. Undersökningen är uppdelad på dels en studie av näringstillståndet i ett antal över hela landet spridda starrmyrar i naturtillstånd och dels en systematisk undersökning av näringshalterna i yttorven från två någorlund homogena torvmarksområden.

Materialet till den förra delen av undersökningen grundar sig på ett antal torvprov, som slumpmässigt insamlats från starrmyrar i naturtillstånd. Huvuddelen av materialet härstammar från norra och mellersta delarna av landet där torvmarksfrekvensen är störst. Torvproven har analyserats för totala och lösliga makronäringsämnen och som bäst förbereds en serie mikronäringsämnesanalyser. Materialets fördelning på de olika torvmarkstyperna samt dess allmänna kemiska egenskaper framgår av tabell 1. Tyvärr är de olika torvmarkstyperna något ojämnt representerade, det visade sig speciellt svårt att finna örtrika varianter i naturtillstånd. Det bör dock beaktas att med torvmarkstyp här avses ett större någorlunda enhetligt växtsamhälle; vegetationstäcket vid provtagningspunkten kan avvika avsevärt från det genomsnittliga på området. Sålunda har till de egentliga starrmyrarna hänförts ett flertal provtagningspunkter med örtarted vegetation, vilka efter en faktorering av materialet kommer att hänföras till de örtrika varianterna.

Tabell 1. Det undersökta materialet och dess allmänna kemiska egenskaper (horisonten 10—20 cm).

Torvmarkstyp	n	Vol.vikt g/dm³	pH H_2O	Aska %	Katjonbyteskapacitet totalt m.e./100 g	Katjonbyteskapacitet utbytbara baser %
Örtrik starrmyr	26	91.7	4.6	7.6	29.6	51
Egentlig starrmyr	86	54.8	4.3	5.1	36.1	44
Lågstarrmyr	43	59.5	4.1	3.7	33.5	35

Resultat och resultatgranskning

Av tabell 1 framgår provens naturliga volymvikt, surhetsgrad, askhalt och effektiva katjonbyteskapacitet samt basmättningsgrad. Intressant är, att den totala katjonbyteskapaciteten tenderar att öka med avtagande trofi medan basmättningsgraden, som väntat, ökar med ökad trofi. I övrigt får tabell 1 anses innehålla helt väntade värden, skillnaderna mellan de olika vegetationstyperna är i de flesta fallen statistiskt tämligen signifikanta. I tabell 2 har sammanställts resultaten av analyserna för totala näringsämnen. Värdena representerar torvskiktet från 10—20 cm djup, vilket skikt enligt bl.a. Vahtera (1955) får anses vara av synnerlig betydelse för trädens näringsupptagning efter en skogsdikning.

Värdena i sig själv uppvisar inga anmärkningsvärda avvikelser från de mängder torven enligt gängse uppfattning innehåller. Det kan dock noteras, ett fosfor och kaliumhalterna är lägre än de som rapporterats av Vahtera (l.c.) för motsvarande torvmarkstyper. Detta kan eventuellt bero av att de sistnämnda värdena avser dikade torvmarker där torvens volymvikt till en följd av dikningen ökat medan träden under omställningsprocessens begynnelseskede ännu inte förbrukat torvens förråd av fosfor och kalium. Vad som i detta sammanhang är av intresse är, att halten av samtliga näringsämnen förutom kalium ökar med tilltagande trofi. Skillnaderna mellan de olika grupperna är trots en avsevärd spridning inom gruppen statistiskt tämlingen signifikanta. Detta gäller dock inte kalium där de egentliga starrmyrarna uppvisar det maximala värdet. De örtrika starrmyrarnas låga kaliumhalt

Tabell 2. Yttorvens (horisonten 10—20 cm) innehåll av totala växtnäringsämnen.

Torvmarkstyp	N	P	K	Ca	Mg
	% av torrvikt				
Örtrik starrmyr	2.25	0.103	0.054	0.542	0.094
Egentlig starrmyr	1.60	0.077	0.079	0.338	0.072
Lågstarrmyr	1.34	0.049	0.052	0.230	0.054

Tabell 3. Yttorvens (horisonten 10—20 cm) innehåll av i 0.05-n svavelsyra lösliga växtnäringsämnen (Starr och Westman 1977).

Torvmarkstyp	N	P	K	Ca	Mg
	mg/100 g torv				
Örtrik starrmyr	99.1	5.8	53.4	373.2	62.8
Egentlig starrmyr	103.7	7.2	65.4	232.3	49.8
Lågstarrmyr	88.9	5.3	29.4	143.2	35.9

får förklaras med deras i genomsnitt höga vattenhalt och torvens stora innehåll av kalcium, vilket gynnat en utlakning av den relativt svagt bundna kaliumjonen.

Samstämmigheten mellan torvens näringshalt och bottenvegetation — virkesproduktion är sålunda, som väntat, tämligen god när man granskar de totala växtnäringsämnena. Analyserar man däremot för lösliga näringsämnesfraktioner blir bilden mera förvirrande (tabell 3 enligt Starr och Westman 1977). Samstämmighet mellan ytvegetation och yttorvens näringshalter råder nu enbart för kalcium och magnesium, vilka vardera uppvisar statistikt tämligen signifikanta skillnader. Detta gäller för näringsämneshalter uttryckta i koncentrationer (mg/100 g); räknar man om dessa till totala mängder (kg/ha) får man ett något bättre samband. Jämför man de lösliga näringsämnesfraktionerna med torvens totalhalter av näringsämnen framgår endel intressanta detaljer. Kvävet och fosforn föreligger till en mycket liten del i tillgänglig form, endast 5—10 % av den totala mängden är extraherbar, vilket noterats tidigare av bl.a. Kaila (1956). Metallkatjonerna däremot föreligger i rätt hög grad i löslig form kalcium och magnesium till 60—70 % medan kalium uppvisar en intressant glidning sålunda, att nästan all kalium är lätt utbytbar i torven från de örtrika typerna medan bara till drygt 50 % i torven från de svagaste växtplatserna. De egentliga starrmyrarna intar en intermediär position.

En geografisk uppdelning av materialet på södra och norra Finland visar en tendens till större kvävemineralisering inom samma växtsamhälle i södra Finland än i norra Finland. Detta tyder på ett större behov av kväve även på bättre växtplatser i norra Finland, vilket i gödslingsförsök även påvisats av Seppälä och Westman (1976). I övrigt synes inte föreligga några systematiska skillnader i geografiskt hänseende.

De ovan presenterade värdena ger sålunda för handen att det finns en viss möjlighet att precisera näringsämnesbehovet för tall på dikade torvmarker. Här har dock lämnats en central fråga öppen d.v.s. analysresultatens tillförlitlighet. Frågan om markens heterogenitet är på inget sätt ny (bl. a. Gjems m.fl. 1969, Troedsson och Tamm 1961, Troedsson och Lyford 1973 samt Falck 1973), men några systematiskt utförda undersökningar från torvmarker torde inte föreligga. För att belysa denna problematik har här som exemple framtagits några serier systematiskt insamlade torvprov, vilka i detta fall analyserats för totalkväve (tabell 4).

Dessa systematiska provserier representerar två någorlund enhetliga torvmarksområden av vilka det ena är en örtrik starrmyr och det andra en relativt torr egentlig starrmyr med ett betydande inslag av risväxter och tuvdun. Vardera områdena är jämfört med motsvarande genomsnittliga växtplatser väl bestockade. På den örtrika starrmyren har det systematiska provet uttagits med 10 m avstånd medan proven från den egentliga starrmyren tagits med olika avstånd (1.0 samt 10 m). Resultatet, som framgår av tabell 4 visar, mot all förmodan, att den torrare egentliga starrmyrens ytskikt uppvisar en större heterogenitet i hänseende till kvävehalten än den våtare örtrika typen. Den okulära uppskattningen av de båda områdena gav intrycket av en avsevärt större ojämnhet i yttorven på den sistnämnda växtplatsen. Eventuellt blir resultatet ett annat då det hela materialet analyseras för samtliga näringsämnen. Proven insamlade med kortare avstånd än 10 m uppvisade en klart mindre heterogenitet, men även här var variationerna betydande.

Tabell 4. Ett exempel på de markkemiska variablernas variationer i yttorven.

	Torvprov												
	1	2	3	4	5	6	7	8	9	10	$\bar{x}$	$S_{\bar{x}}$	n3)
	Totalkväve, mg N/g torv											%	
	Försöksfält A1)												
10 m Avstånd													
Horisont 0—10 cm	18	16	16	26	23	24	19	19	17	23	20.0	5.5	30
	Försöksfält B2)												
10 m avstånd													
Horisont 0—10 cm	8	9	13	11	14	9	9	15	11	13	11.0	7.2	82
Horisont 10—20 cm	14	12	15	14	15	13	14	16	16	20	15,1	4.1	29
Horisont 20—30 cm	15	12	17	17	19	17	19	18	22	20	17.4	5.3	45
1 m avstånd													
Horisont 0—10 cm	12	10	14	12	11	13	15	12	22	10	12.2	3.4	26

1) Örtrik starrmyr.

2) Egentlig starrmyr med ett betydande inslag av risväxter samt tuvdun.

3) Antalet erforderliga delprov för att påvisa en 10 % stor skillnad med 95 % säkerhet på 5 % risknivå.

Jämför man prov från olika torvskikt med varandra framgår, att heterogeniteten verkar avta djupare ner i torven. Detta förutsätter givetvis att det inte sker någon förändring torvavlagringens stratigrafi, vilket troligen skett mellan horisonterna 10—20 cm och 20—30 cm på försöksfält B (tabell 4). Allmänt taget visar resultaten, att det med tanke på en praktisk tillämpning erfordras ett avsevärt antal delprov för att på ett tillfredsställande sätt karaktisera näringstillståndet i en större torvmarksareal. Enligt de, på basen av det här presenterade materialet, framräknade värdena fordras det för att med 95 % säkerhet på 5 % risknivå påvisa en 10 % stor skillnad mellan generalprov från hela fältet B hela 82 delprov (horisonten 0—10 cm). Motsvarande värde för fältet A är 30 delprov.

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CHANGES IN THE AMOUNTS OF INORGANIC NUTRIENTS IN THE SOIL AFTER CLEAR-FELLING

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Investigations of the water quality of the streams flowing through forested areas have shown that the amounts of inorganic nutrients in the stream water increase after clear felling (Likens, G. E., Bormann, F. H. et al. 1970, Fredriksen, A. L. 1971, Wiklander, G. 1974). Taking into consideration the great amounts of inorganic nutrients added to the soil with the slash, it is not surprising that part of these are leached out from the soil. A corresponding loss ought to be found in the clear-felled area. What possibilities do we have of finding such a loss by soil investigations and how much of the added inorganic nutrients are taken up by the field- and ground vegetation?

In order to get an answer to these questions, some figures from two investigations of clear-felled areas have been brought together.[1] One area is situated in the southern part of the province of Dalecarlia (Garpenberg) and the other in the province of Västerbotten, about 100 km WNW of Umeå (Flakaträsk) (Tab. 1).

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[1] Parts of this investigation have been published in 1974a, 1974b and 1977 but most of it is still unpublished.

Tab. 1. Descriptions of sites and stands before clear felling.

Characteristic	Garpenberg	Flakaträsk
Location	lat. N60° 16′, long. E16° 13′	lat. N64° 15′, long. E18° 30′
Altitude	200—220 m above sea level	420—450 m above sea level
Exposition	ENE 4 %	SSE 7 %
The size of the experimental area	3.7 ha	2.9 ha
Rock type	Granite	Granite
Textural soil type	Sandy till	Sandy till
Soil profile type	Podzol	Podzol
Humus layer type	Mor	Mor
Forest vegetation type	Mesic dwarf-shrub	Mesic dwarf-shrub
Stand age	100 (45—132)	139 (128—160)
Height of tree of mean basal area	22.6 m	17.0 m
Number of trees per hectare	544 (spruce 493, pine 40, deciduous trees 11)	1002 (spruce 988, pine 9 deciduous trees 5)
Basal area (breast height)	29.8 m^2/ha	33.5 m^2/ha
Basal area weighted mean diameter	26.4 cm	20.6 cm
Form factor (spruce, breast height)	0.464	0.486
Mean volume	331 m^3 sk/ha	278 m^3 sk/ha
Site quality class	4.9 m^3 sk/ha, year	2.6 m^3 sk/ha, year

Results

The amounts of nitrogen, phosphorus potassium, calcium and magnesium in the slash, field and ground layer vegetation and the humus layer are shown in Figs. 1—5. The amount of nitrogen found in the field and ground layer vegetation after clear-felling is 6—13 % of the amount of nitrogen in the slash added to the soil. Corresponding figures are for phosphorus 5—11 %, potassium 20—41 %, calcium 1—2 % and for magnesium 3—9 %. The uptake of inorganic nutrients by the vegetation decreases the leaching losses from the soil. Therefore the grasses and herbs usually invading a clear

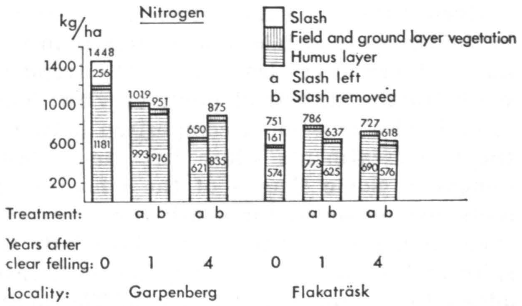

Fig. 1. The amount of nitrogen in the slash, field and ground layer vegetation and humus layer. In kg per ha.

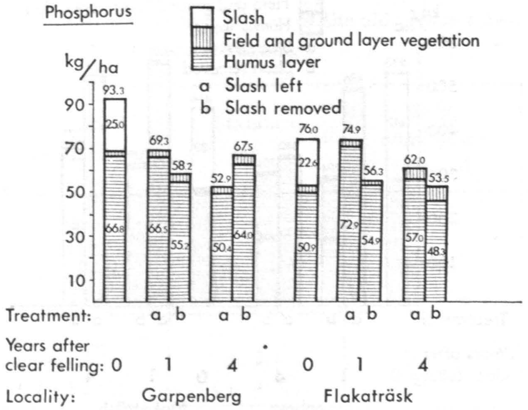

Fig. 2. The amount of phosphorus in the slash, field and ground layer vegetation and humus layer. In kg per ha.

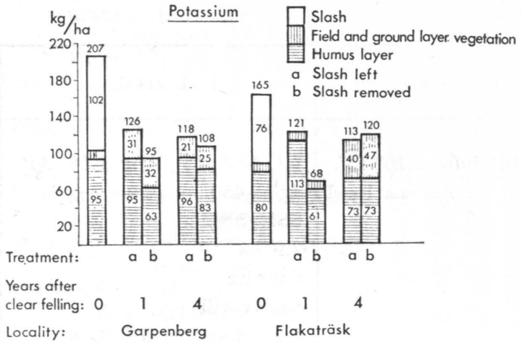

Fig. 3. The amount of potassium in the slash, field and ground layer vegetation and humus layer. In kg per ha.

felled area are of great importance in retaining the inorganic nutrients, especially potassium, within the ecosystem.

When the amounts of inorganic nutrients in the slash are added to those of field and ground layer vegetation and humus layer of the old spruce forest, the figures are in most cases higher than those for the clear-felled areas with the slash left after clear felling (see figs 1—5). This is more pronounced at Garpenberg than at Flakaträsk where even an increase in calcium and nitrogen has been noticed one year after clear felling.

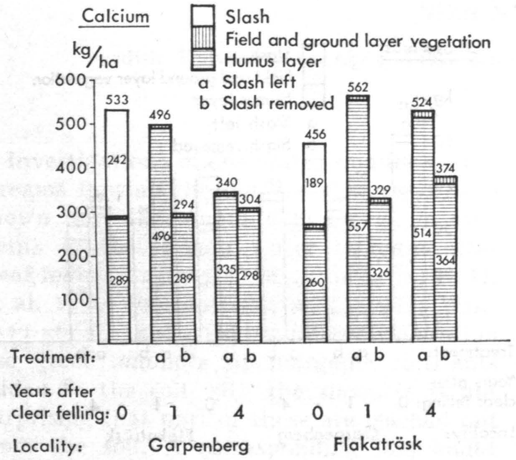

Fig. 4. The amount of calcium in the slash, field and ground layer vegetation and humus layer. In kg per ha.

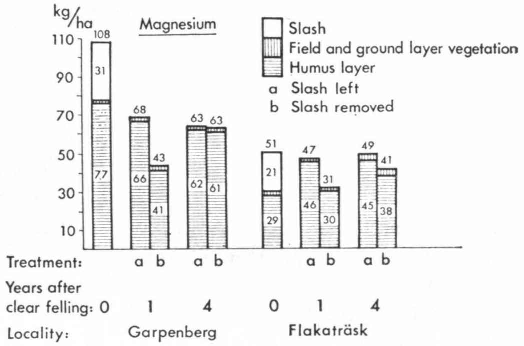

Fig. 5. The amount of magnesium in the slash, field and ground layer vegetation and humus layer. In kg per ha.

The amounts of inorganic nutrients are also greater for »slash left» than for »slash removed» after clear-felling, with the exception of the figures for nitrogen and phosphorus four years after clear felling at Garpenberg. These exceptions are due to the high amounts of humus found when sampling the plots with »slash removed» from the clear-felled area (Fig 6). For potassium a somewhat higher figure has been found at Flakaträsk four years after clear-felling in plots with »slash removed» compared to »slash left». The reason for this is a higher biomass of the field layer vegetation in the plots with »slash removed» than in plots with »slash left».

Discussion

Even if there is a general decreasing trend in the amounts of inorganic nutrients in the humus layer after clear-felling, the trend is weak from a statistical point of view. The same is also true for a comparison between the two treatments »slash left» and »slash removed». Some figures of the amounts of inorganic nutrients for »slash removed» are even higher than those for »slash left» in spite of the amounts of inorganic nutrients added to the soil with the slash. The main reason for this is the heterogenity of the soil which gave high standard deviations for the means, especially for the amounts of humus.

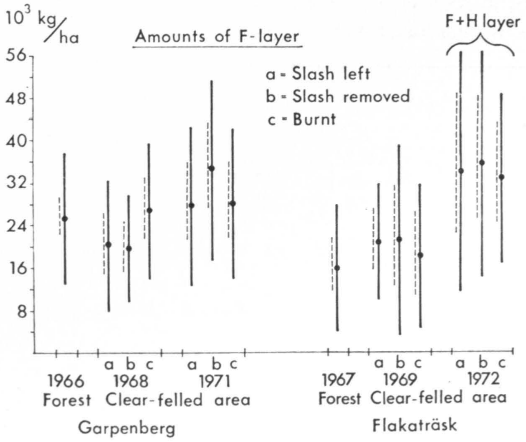

Fig. 6. Amounts of humus per hectare. F-layer. Dry weight 105° C. Each mean is based on 15—20 samples (50 × 50 cm) from the clear felled areas and 44 and 31 samples (50 × 50 cm) from the old spruce forest at Garpenberg and Flakaträsk respectively. The vertical bars indicate ± one standard deviation of the mean. The standard deviation is calculated according to

$$\left[\frac{\Sigma(X_i - \overline{X})^2}{N-1}\right]^{\frac{1}{2}}$$

The vertical dotted bard indicate the 95 % confidence intervals.

The figures for the amounts of humus and inorganic nutrients in the humus layer have been obtained by adding the corresponding figures for the S-, F- and H-layer together. To give an idea of the reliability of the figures, the means, standard deviations, standard errors and 95 % confidence intervals for the concentration of nitrogen, amounts of humus layer and amounts of nitrogen are shown in Table 2.

The figures are from the old spruce forest at Garpenberg where the greates number of samples have been taken. The 44 samples were arranged in 8 composite samples and analyzed. The large number of samples gave comparatively low figures for standard deviations and 95 % confidence intervals. The figures are much higher for the clear-felled areas where smaller numbers of samples have been taken and the sampling was more difficult due to a change in the humus layer after clear-felling. (Fig. 6).

Troedsson & Tamm (1969) have investigated sampling procedures and the number of samples needed to achieve satisfactory results. One of the two investigated areas was the old forest at Garpenberg, i.e. the same area as that described in this report. The sampling plot, with a size of 9 × 11 m, was selected as uniformly as possible. One sample was taken from each square meter of the plot with a cylindrical core sampler having a cross sectional area of about 1 dm², which means that about one percent of the area was investigated. The number of samples was 98.

The mean and relative standard deviation

Tab. 2. Concentration of nitrogen and amounts humus and nitrogen in the F-layer of the old spruce forest at Garpenberg. The figures are based on 44 samples arranged in 8 composite samples.

Variable	Mean	Standard deviation	Standard error	95 % confidence interval
Concentration N %	1.5	± 0.20 (±13 %)	± 0.07 (± 5 %)	± 0.17 (±11 %)
Amount of humus .... 10³ kg/ha	25.8	± 3.2 (±12 %)	± 1.1 (± 4 %)	± 2.6 (±10 %)
Amount of N kg/ha	435	±87 (±20 %)	±31 (± 7 %)	±73 (±17 %)

Tab. 3. Concentration and amounts of nitrogen in the humus layer of the old spruce forest at Garpenberg (Troedsson and Tamm 1969) and in the humus layer of a pine forest in Hälsingland. (Falck 1973).

Variable	Number of samples	Mean	Standard deviation	Standard error	95 % confidence interval
TROEDSSON & TAMM 1969 Amount of N in the humus layer kg/ha	98 subsamples	945	±278 (± 29 %)	± 28 (± 3 %)	± 56 (± 6 %)
	20 subsamples	1149	±506 (± 44 %)	±113 (± 10 %)	±236 (± 20 %)
FALK 1973 Concentration N %	6 composite samples (each 25 subsamples)	0.63	± 0.04 (± 6 %)	± 0.015 (± 2.4 %)	± 0.04 (± 6 %)
Amount of N .... kg/ha		376	± 23 (± 6 %)	9.4 (± 2.5 %)	± 24 (± 6 %)

of the amount of nitrogen per ha in the humus layer were 945 kg N± 29 % (Table 3). When 20 samples, each about 4 dm², were cut out with a knife from the same selected area, the corresponding figures were 1149 kg N± 44 %. The means coincide with the amount of nitrogen in the humus layer of the old spruce forest given in this report viz. 1181 kg N per ha (cf. Fig 1).

The relative standard deviations obtained by TROEDSSON & TAMM (1969) were comparatively high in spite of the small size of the selected areas. Such a high relative standard deviation for the amount of nitrogen in the humus layer was obtained also by FALCK (1973) when calculated on subsamples, but only 4—9 percent when based on 6 composite samples, each consisting of 25 subsamples, i.e. in all 150 subsamples per plot (Table 3).

Comparatively large humus samples (50 × 50 cm) have been used in the present investigation and the sampled areas were 11 m² and 8 m² for the old spruce forests of Garpenberg and Flakaträsk respectively. In the clearfelled areas the sampled areas were about 2—2.5 m² for each plot 50 × 50 m. The size of the samples is, however, not so important compared to the number of samples (FALCK 1973). Except for the importance of having many samples randomly distributed over the area, one reason is probably the more or less decomposed logs and small depressions containing large amounts of humus which are common in temperate forest soils. If the irregularities in the humus layer should be smaller, the variations within a sample would be levelled out and a large sample could represent a composite sample.

TROEDSSON & TAMM (1969) have investigated small selected plots of about 100 m² and FALCK (1973) trial plots of 20 × 30 m. In the present investigation the plots in the clear-felled areas were 50 × 50 m. The standard devaition for the same number of samples increases with the size of the investigated area. Thus, FALCK (1973) has found differences in the amounts of inorganic nutrients between 6 adjacent plots.

The relative standard deviation of the amount of humus in the F-layer from the clear-felled areas was very high in most cases. The highest figures obtained were 94 and 74 % (cf. Fig. 6). The main reason is probably the drastic change in the vegetation after clear-felling which also causes a change in the uppermost soil layer. The original rather distinct mor layer is being more mixed with the mineral soil, mainly as a result of the roots of grasses and herbs penetrating deeper into the mineral soil than the roots of the original vegetation. Thus, the boundary between humus and mineral soil levelled out to a certain extent after clear-felling. Such a change made the sampling of the humus layer more difficult in the clear-felled area than in the old spruce forest.

The difficulties involved in drawing distinct boundaries between humus layer and mineral soil suggest that the mineral soil is also included when making comparisons between different treatments of the clear-felled areas. However, the mineral soils are mostly so heterogenous and the amounts of inorganic nutrients so great, that it is not possible to refind such small amounts of inorganic nutrients as those of slash added to the soil after clear-felling. Figures for the amounts of some inorganic nutrients in the mineral soil are given in NYKVIST (1977).

Forest soils are usually very heterogenous and this investigation has shown the difficulties involved in getting reliable results about the amounts of inorganic nutrients from soil investigations. The investigation deals with inorganic nutrients in the slash added to the soil when clearfelling, but it is certainly valid also for the supply of inorganic nutrients by fertilization.

It is of prime importance to forestry to get more information about the loss of inorganic nutrients after clear-felling or fertilization. However, it does not seem possible to get that information only by soil investigations, at least not if the forest stands are comparatively large. The reason for this is the great heterogenity of forest soils and the small amounts of inorganic nutrients added to the soil compared with the great amounts in the soil, especially in the mineral soil. The best method of obtaining such information is by the small water-shed approach. This method has been used, e.g. at the Hubbard Brook Experimental Forest by LIKENS, BORMANN et al. (1977) and in western Canada by KIMMINS & FELLER (1976) with very good results.

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PLANT NUTRIENT BALANCE IN DECORATION GREENERY CULTIVATION

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Introduction

In the normal high forest system a considerable amount of the plant nutrients are re-circulated through the litter. This re-circulation is essential for the preservation of the fertility of the soil. Localities which have long been forested have a stable and comparatively high degree of fertility. It is characteristic that in the so-called old forest areas of Denmark the application of plant nutrients usually produces no visible effect.

Where re-circulation is broken, the soil will rather soon be come exhausted. The results of »Streunutzung» and »Reisignutzung» are well-known. Thus, van Goor and Tiemens (1963) measured a fall in increment of 25 per cent during a 7-year period after a single experimental Streunutzung in Scots pine stands. It is worth mentioning that Beneš (1961) has suggested that the forests of Bohemia-Moravia should be divided into zones for the purpose of regulating brushwood utilization. It is said about the most fertile localities that »Der Verfasser empfiehlt, in diesem Gebiet den Reisig voll zu nutzen».

If some means of protecting the ecosystem is introduced, the time it will take to rebuild the fertility of the system will vary. This has been known through the centuries and is still utilized today in the farming system that is termed shifting cultivation (see for instance Watters, 1971).

Cultivation of decoration greenery

The production of decoration greenery and, for that matter, also the production of Christmas trees break the re-circulation. The marketed product consists of needles on a small framework of branches and twigs. Where cultivation is very intensive, in theory neither needles nor small twigs etc. will fall to the ground. There is a considerable degree of nutrient export from the area, and this must be counteracted by applying plant nutrients (replacement fertilization). The amount of plant material removed totals from 5 to 10 tons per hectare per annum.

Methods of investigation

The obvious solution is to base a replacement fertilization program on the chemical composition of the produce. In the autumn of 1967 a three-year study was commenced. A three year period was chosen as that the effect of climatic factors would be evened off. Four representative *Abies nobilis* stands which had been cut for a number of years were chosen. In each stand 3–5 typical trees were selected, which were placed in 3 groups (A–C), consisting of 5 trees each (nos. 1–5). The treatments were as follows –

A. Whorl no. 4 counted from the top was cut every year. In 1967 all lower whorls were removed.
B. Whorl no. 5 counted from the top was cut every year. In 1967 all lower whorls were removed.
C. Whorl no. 6 counted from the top was cut every year. In 1967 all lower whorls were removed.

Harvesting was carried out at the normal time, that is November. After trimming to normal marketable commodity specifications, representative samples of parts of this commodity were selected, and the samples weighed, dried, weighed (dry matter determination), pulverized and analysed for the plant nutrients shown in Table 1. For further details, see Holstener-Jørgensen 1972).

Table 1. Average nutrient concentrations (% or ppm of dry matter) in *Abies nobilis* of cuttings in various whorls, and amounts of nutrients (kg or g) per 1000 kg marketable commodity. The calculation is based on the general dry matter ratio: 404 kg/1000 kg marketable commodity.

Nutrient	Average concentrations and total amounts of nutrients					
	Cutting at the 4th whorl		Cutting at the 5th whorl		Cutting at the 6th whorl	
	%	kg	%	kg	%	kg
N	1.33	5.4	1.21	4.9	1.13	4.6
P	0.145	0.59	0.117	0.47	0.110	0.44
K	0.54	2.2	0.47	1.9	0.47	1.9
Mg	0.107	0.43	0.097	0.39	0.092	0.37
			Average for the whole material			
			%	kg		
Ca			0.49	2.0		
Na			0.026	0.11		
			Average for the whole material			
			ppm	g		
Mn			506	204		
Zn			75	30		
B			22	9.0		
Mo			0.66	0.30		
Cu			9.1	4.0		

Results

Table 1 shows some average results from the investigation. Nutrient concentrations are included, and the amounts of nutrients expressed in kilos which have been removed with each ton of marketable decoration greenery have been calculated. It appears that the amount of nutrients removed per 1000 kg decoration greenery is greatest when the youngest branches (4th whorl) are harvested. This is due to the fact that the needle weight / total weight ratio is greatest in these branches.

Ingestad (1974) has published internal nutrient weight proportions required for maximum growth of young seedlings of$^{1)}$ cowberry and bilberry,$^{2)}$ birch and $^{3)}$ cucumber. Fig. 1 has been drawn on the basis of Ingestad's figure showing the four species, and average values for *Abies nobilis* have been added. Differences between the *Abies nobilis* values and the values charted by Ingestad may be explained by differences in the natural nutrient concentrations of the analysed material. The *Abies nobilis* samples contain relatively high proportions of wood and bark, the nutrient ratios of which must presumably be different to those of the

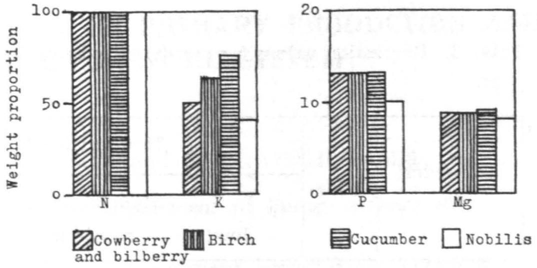

Figure 1. Internal nutrient weight proportions required for maximum growth of young seedlings of$^{1)}$ cowberry and bilberry, $^{2)}$ birch, and $^{3)}$ cucumber (after Ingestad, 1974), a well as values for *Abies nobilis* according to chemical analysis of produce (Holstener-Jørgensen, 1972).

Table 2. Nutrient ratios of commercial fertilizers which are marketed in Denmark. (After Superfos 1974/75).

Fertilizer	Nutrient ratios			
	N	P	K	Mg
14-4-17 with Mg + Cu	100	27.2	122.8	7.4
18-5-12 with Mg + Cu	100	27.2	65.0	10.0
16-5-12 with Mg	100	31.3	75.0	7.5
21-4-10 with Mg	100	17.8	46.2	4.8
23-3-7 with Mg + Cu	100	12.8	29.2	7.1
24-3-7	100	11.0	27.8	
25-3-9	100	11.8	36.6	
Nitrophoska	100	43.0	117.4	10.7
According to product analyses (Table 1 average)	100	10.1	40.3	8.1

growing parts of shoots. Otherwise, the differences are relatively small.

Replacement fertilization based on the knowledge of how great amounts of nutrients are removed in the sale of decoration greenery will be easiest to carry out if a mixed fertilizer suitable for this purpose can be found. Table 2 shows nutrient ratios of commerciale fertilizers that are marketed in Denmark. The last line indicates the nutrient ratios as determined by yield analyses. It appears that none of the marketed commercial fertilizers have an ideal composition. We have ended up by recommending the use in practice of 23–3–7 including Mg and Cu and occasionally storage-fertilizer with K. The Cu-content of this fertilizer is stated to be 0.1 per cent.

The effect of replacement fertilization

In conclusion an account shall be given of the effects of replacement fertilization based on yield-analysis results. 15 pairs of plots consisting of 1 non-fertilized and 1 replacement-fertilized plot of *Abies nobilis* were set up throughout the country. The 15 pairs of plots are of different age and structure, and the cutting intensity varies from pair to pair. The fertilization of the fertilized plots has consisted of an initial fertilization with 1500 kg Nitrophoska per hectare and then replacement fertilization after each harvest with 7.6 kg N per 1000 kg cutting + the other nutrients corresponding to the application of 23-3-7 with Mg and Cu. It can be seen that the amounts, 7.6 kg N, is somewhat greater than what the figures in Table 1 would suggest is necessary. The larger dose has been fixed in accordance with the highest analysis values that form the basis of Table 1, since the stands used for the yield analyses had not been fertilized.

Table 3. Regression values for non-fertilized and fertilized plots. Kg marketable greenery per hectare and year.

Diameter cm	Unit	Non-fertilized			Fertilized		
		Stem number			Stem number		
		low	medium	high	low	medium	high
5	kg	8190	9182	10173	10816	12695	14575
	rel.	100	100	100	132	138	143
10	kg	5480	7030	8581	6277	9217	12156
	rel.	100	100	100	115	131	142
15	kg	2795	4892	6989	1787	5763	9738
	rel.	100	100	100	64	118	139

Table 3 shows the results from the years 1967–1971. It appears that the central values in the table show effects of the order of 30 per cent. For further details, see Holstener-Jørgensen 1973.

These experiments are now being readjusted, so that the plots that have so far been non-fertilized will subsequently be replacement-fertilized with doses corresponding to those which the fertilized plots have had up till now, whereas the doses are doubled in the plots so far fertilized.

Concluding remarks

The program that has been outlined above has borne fruit in the shape of a practically applicable fertilization program, as it appears, *inter alia*, from Table 3. In fact, as far as the author is informed, also today, 10 years after the start, the program is used practically everywhere in Denmark.

In principle it is an attractive idea to replacement-fertilize with a balanced amount of nutrients. As suggested by Ingestad (1974), it should be possible to avoid »wasteful fertilizing practices» both as regards economical points of view, resource considerations, quality of produce, and pollution problems. It should be pointed out, however, that the program reviewed above should be considered only a first approach. For one thing, the analyses are based on non-fertilized, cut stands, which may have and an unbalanced nutrient status, and for another, there are so many problems not yet elucidated which may render the interpretation of the analysis results difficult. Holstener-Jørgensen (1972) has noticed the effect that lopping of green twigs may have on the nutrient relations; for instance, a relative increase in the N-content. Attention may also be drawn to the fact that, under given ecological conditions, an excess of certain ions may occur, so that the yield analyses do not reflect optimum nutrient relations.

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THE EFFECT OF FOREST FERTILISATION ON PRIMARY PRODUCTION AND NUTRIENT CYCLING IN THE FOREST ECOSYSTEM

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The changes brought about in primary production and nutrient cycling by forest fertilisation must be considered in the context of the basic properties of the ecosystem and its components. This paper will concentrate, however, on changes in biomass and associated changes in primary production and nutrient circulation between soil and vegetation.

In its undisturbed condition the forest ecosystem has a relatively closed nutrient cycle. External supply to the system, and losses from it, are small both absolutely and in comparison with the amounts cycling within the system (cf. BRINGMARK). It should be noted, however, that the wet and dry deposition of some elements, nitrogen and sulphur in particular, is increasing with increasing industrialization.

Practical forest fertilisation is based on the fact that forest growth is often limited by lack of available nutrients, in the boreal forest most often nitrogen. This does not exclude the possibility that other factors (temperature, water supply, etc.) may also limit growth, regularly or on certain occasions. It is also possible that part of a fertiliser effect may be indirect, by stimulation of organisms other than the trees, or soil processes.

The ability of different plant species to react to change in the nutrient supply depends on several factors. One of the most important is the genetically determined potential for growth, which affects both the timing of the growth response and its size. In Norway spruce and Scots pine the number of shoots, the growth of each shoot and its number of needles is largely already determined at the time when the bud is formed. This implies a time lag of at least a year in the growth response. The diameter growth of the tree stem is probably less directly predetermined, but on the other hand it depends on the size of the green crown (BECKWITH & SHACKELFORD 1976; cf. also FAGERSTRÖM & LOHM 1977), which results in a time lag in this reaction, too. Larch and hardwoods usually have a smaller degree of predetermination, which means a faster reaction to fertilisation. An extreme case is represented by weeds, and herbs such as *Chamaenerion angustifolium*, which rapidly increase their biomass if conditions are favourable.

There are also genetically conditioned differences in the mechanism of photosynthesis. Such differences may have a biochemical background or may depend on anatomical properties which cause differences in diffusion resistance for carbon dioxide in the needles. Other possible causes may concern the sensitivity of the stomata to changes in water supply. LINDER & INGESTAD (to be published) show that fertilisation may change the efficiency of photosynthesis in pine needles by about fifteen per cent. This is probably the order of magnitude to be expected for the response in production, if a biologically closed stand is fertilised. MILLER & MILLER (1976) have measured a greater increase in »net assimilation rate» in fertilised Corsican pine, but their stand was said to suffer from severe deficiency in nitrogen.

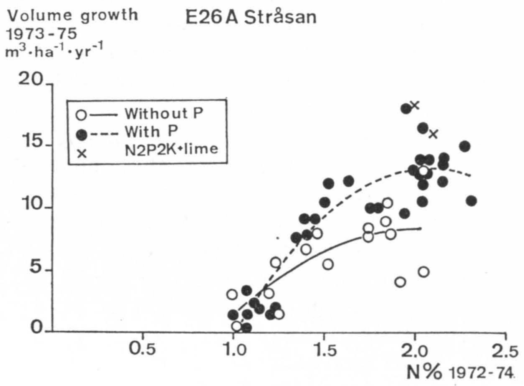

Fig. 1. Current volume increment on sample plots as a function of the nitrogen content in exposed current needles.

Boreal forests are often not very densely stocked, and it takes a long time before young trees form a closed canopy on a cleared area. In this case the excess of photosynthetic products may be used for increasing leaf biomass. The response in production may then in extreme cases be several hundred per cent (Fig. 1).

As mentioned above, the primary effect of supplying a production — limiting nutrient is an increase in photosynthetic tissues and, usually to a lesser degree, in photosynthetic efficiency. Table 1 shows how needle biomass increases after fertilisation in a young pine stand. Table 2 shows how the reaction can be explained by changes in different crown components. There seems to be a slight increase in the number of first-order lateral branches (and most probably also in second and third-order branches), while the length of branches formed after the start of fertilisation is approximately the same as on control plots. Branch diameter, number of needles and weight of

Table 1. Needle dry weight (kg · ha^{-1}) of a young pine stand (E40 Lisselbo) fertilised with ammonium nitrate annually from 1969 onwards. Sampling in early spring, 1975.

Needle age	Treatment				
	0	N1	N2	N3	N2P2K2
Current (C)	1191	2298	2495	2415	2531
C + 1	1169	2454	2774	2464	2648
C + 2	935	1962	1725	1146	1322
C + 3 +	318	604	278	188	131
Total	3613	7318	7272	6213	6632

Table 2. Responses to fertilisation (N1, N2, N3 and N2P2K2) in branch and needle characteristics. Experiment E40 Lisselbo, fertilised from 1969 onwards. All figures in per cent of controls.

Branch whorl	Arithmetic means from lateral branches						
	number*	diameter	length	number of needles		single needle weight	
				C	C + 1	C	C + 1
0	107	—	—	—	—	—	—
1	111	104	99	95		124	
2	114	96	92				
3	113	100	94				
4	105	135	104	158	139	135	141
5	103	119	113				
6	84	150	127				
7	100	116	114	127	132	133	143
8	98	130	114				
9	95	112	109				
10	93	101	102				
11	107	100	106	138	151	128	154

* Living + dead branches and for whorl »0», lateral buds. Whorl 0 corresponds to the year 1975 and whorl 5 is the first whorl wich could have been affected by the treatment already from budsetting.

Table 3. Nutrient content in spruce needle litter collected Nov. 1968—Nov. 1969. Hökaberg, Remningstorp. All values in per cent dry weight. (From Tamm 1971).

Treatment	Plot No.	N	P	K	Ca	Mg	Mn
Control	8	0.90	0.09	0.30	1.96	0.10	0.25
	14	0.94	0.10	0.33	1.77	0.10	0.25
PK	6	0.96	0.12	0.42	2.12	0.10	0.27
	7	0.86	0.12	0.33	2.18	0.10	0.28
N2PK	4	1.39	0.10	0.33	1.81	0.10	0.26
	13	1.61	0.11	0.35	1.62	0.09	0.26
N4PK	9	2.03	0.08	0.26	1.44	0.08	0.42
	11	2.11	0.09	0.29	1.19	0.07	0.43

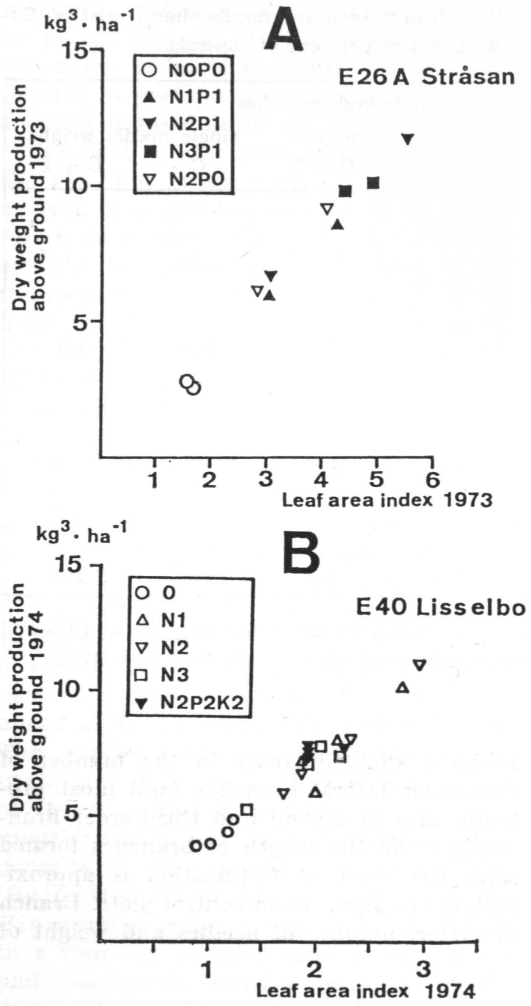

Fig. 2. Dry weight production above ground as a function of leaf area index (projected area). A: the spruce stand in the experiment Stråsan. B: the pine stand in the experiment Lisselbo. Each symbol represents one plot. The calculation of production values involves certain assumptions, for the Stråsan data described by Tamm (1974) and for the Lisselbo data by Albrektson (manuscript).

individual needles increase markedly on fertilised trees.

There is also a possibility that an increase in efficiency of other organs, e.g. root systems, may occur if phosphorus is supplied, but even in this case it is probable that the leaf area eventually increases, leading to an increased level of productivity.

The increase in leaf biomass will only increase plant production as long as self-shading is not too great (Fig. 2 A and B). The positive relation between leaf area and the production of stems and branches is well known (Tamm 1974, Beckwith & Shackelford 1976), but less well documented in the case of root production. The increased plant biomass contains more plant nutrients, even if the concentrations of nutrients not supplied will sometimes decrease (»false antagonism»).

The increased plant production leads to increased litterfall in pine, with a time lag of two to four years, in spruce with a time lag of six to eight years (Table 4). There will also be an immobilisation of plant nutrients in the more persistent parts of the tree stem and in the coarse branches. While the amounts immobilised may not usually make up a large part of the nutrients added, it should be mentioned that in extreme cases, on drained, unfertilised peatlands deficient in potassium, Holmen (1964) found that the stand contained about half of the total store of potassium in the ecosystem.

The quality of the litter may also be changed (Tab. 3, 4 cf. Tamm 1971, Miller et al. 1976). When tissues die, the redistribution of plant nutrients seems to be less efficient in fertilised than in unfertilised trees. There is also a possibility that the proportions of different components in the litter may be changed, even if there is no direct evidence for this. Fertilised young pines often develop the characteristics of »wolf trees», which may lead to an increased proportion of branch wood and branch bark, which will be returned to the ground after a long period. As a rule only a small proportion of added plant nutrients can be accounted for in the trees (Tamm 1963, Heilman & Gessel, 1963, Björkman et al. 1967). It is therefore not very likely that the changes in the amounts of litter and in the quality of the litter should play a decisive, direct part in nutrient cycling. On the other hand, it is quite possible that an increase in the litter supply, caused by fertilisation, may result in an improvement in soil-biological conditions on some soils, because the decomposers will have more organic matter (more subtrate). In the case of practical forest fertilisation, this is probably more important than the changes in the amount of nutrients in the substrate.

Table 4. Nutrient concentrations in pine needle litter from experiment E42 Lisselbo, collected May 1971 — Sept. 1973. All element concentrations in per cent dry weight. Average from 80 littertraps on unfertilised plots (—) (treatments: control, irrigation, »acid 1», and »acid 2») and 80 littertraps on fertilised plots (+) (the same treatments + N2P2K2, see Tamm et al. 1974). Monthly samples bulked for analysis. Values from a few plots missing in the first column.

Treatment		1971			1972			1973		1971—73 D. M. weighted averages
		Summer	Autumn	Winter	Summer	Autumn	Winter	Summer	Autumn	
N	—	0.77	0.48	0.56	0.72	0.41	0.44	0.54	0.46	0.45
	+	1.18	0.75	0.80	1.21	0.64	0.68	0.84	0.68	0.72
P	—	0.045	0.021	0.028	0.042	0.021	0.019	0.028	0.024	0.023
	+	0.059	0.025	0.031	0.051	0.022	0.022	0.032	0.022	0.025
K	—	0.136	0.067	0.072	0.139	0.085	0.048	0.092	0.094	0.074
	+	0.167	0.070	0.056	0.172	0.094	0.061	0.094	0.098	0.086
Ca	—	0.38	0.47	0.44	0.40	0.50	0.54	0.47	0.56	0.50
	+	0.48	0.50	0.50	0.40	0.47	0.48	0.48	0.50	0.49
Mg	—	0.056	0.052	0.049	0.058	0.050	0.043	0.052	0.048	0.048
	+	0.066	0.054	0.042	0.054	0.050	0.043	0.052	0.052	0.050
Mn	—	0.100	0.117	0.110	0.093	0.117	0.117	0.099	0.123	0.118
	+	0.114	0.126	0.108	0.088	0.104	0.095	0.092	0.105	0.104
Dry weight (kg/ha)	—	44	162	24	20	221	289	46	208	
	+	66	99	52	38	453	564	159	374	

There is also a possibility that the qualitative changes in the litter from the field layer will be of importance. On fertilised plots there is often more grass litter with the same or less litter from dwarf shrubs (Fig. 3 B). However, the field layer vegetation is usually a small proportion of the litter-producing vegetation, except in very young or very open stands (Fig. 3 A and B).

Fertiliser application may cause »burning» effects on the lesser vegetation, field layer and bottom layer (both mosses and lichens). The occurrence of such effects is rather irregular, and may depend both on the type of formulation used and on the weather conditions at fertilisation and during the period after application. In practical fertilisation these effects will usually have a rather temporary effect. However, some decrease in reindeer carrying capacity can be expected, if areas with reindeer lichens are fertilised, with an increase in tree canopy cover as a consequence.

A serious disturbance of the nutrient cycling was first observed in Finland (Huikari 1974, 1977), on soils supplied with large amounts of fertiliser. It has been related to deficiency in micro nutrients, boron in particular. In Sweden we have studied damage observed on young pine trees in the optimum nutrition experiment Lisselbo. The damage began after severe

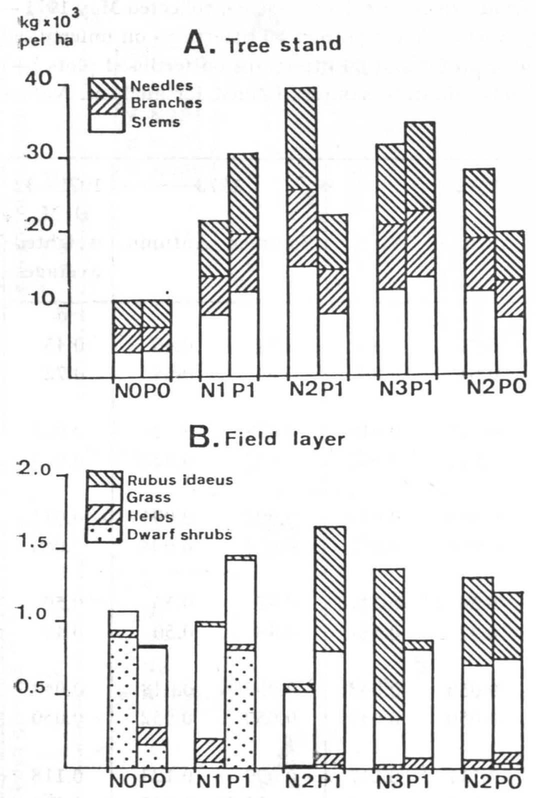

Fig. 3. Biomass above ground within five of the treatments in the Stråsan experiment. Each column represents one plot.

late frosts in 1971 and it has been shown that pines damaged in that year have frost rings in the xylem (Aronsson, manuscript). The needle tissues are also susceptible to frost damage in freezing experiments, more susceptible the higher is the nitrogen concentration (above about 1.7 per cent nitrogen of dry weight). However, analyses of the boron content also show a good relationship between damage recorded in the field and the average boron content within the experimental plots. The worst damage and the lowest boron concentrations were found on plots receiving NPK + lime (cf. Table 5). It is known that liming aggravates a deficiency in boron. Thus it seems that intensive fertilisation without boron may induce deficiency damage (or damage due to climatic conditions, but depending on lower frost resistance in trees suffering from deficiency in boron). Damage of this kind appears to be common in Finland and has been observed on several occasions in Sweden without, however, the causal relationships' being revealed. There are not many indications that forest fertilisation induces other deficiencies in macro or micro nutrients on forest land in Scandinavia. However, deliberately unbalanced fertilisation will lead to deficiencies and both potassium and magnesium deficiency have been observed in forest nurseries.

Table 5. Concentrations of boron (mg/kg air dried sample) in exposed current pine needles from optimum nutrition experiments. Fertilising annually from 1969 (Lisselbo) and 1971 (Norrliden and Åheden). Samples from 1975 and 1976 respectively. Averages for the number of plots in brackets. For further information on the experimental areas Norrliden and Åheden, see Holmen et al. 1976. (Elements in brackets added to some but not all plots)

Treatment	Experiment		
	Lisselbo	Norrliden	Åheden
Control	11.6(4)	10.8(2)	5.9(2)
N2P2K2 (Mg, S)	3.2(6)*	2.9(4)	3.4(2)
Lime	4.2(2)	8.0(2)	
N2P2K2 + Lime	1.9(2)	3.0(2)	
N2P2K2 (Mg, S) + micronutrients	46.8(4)*	37.2(2)	

* One plot without P2.

As the vegetation usually takes up a minor part only of the nutrients added with fertilisers, the remainder will in most cases stay in the soil for a longer or shorter period, subject to both physical chemical, and biological processes, such as ion exchange, immobilisation, leaching, as described by Nömmik (1977).

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FÖRÄNDRINGAR I HUMUSLAGRET EFTER SKOGSGÖDSLING

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Skogsgödslingen påverkar inte enbart vegetationstäcket, inkl. trädbeståndet, utan den lämnar i många fall påtagliga spår efter sig även i marken. Detta gäller i första hand den övre delen av markprofilen, dvs förna- och humushorisonterna.

Vad beträffar förändringarna i marken, kan det röra sig om antingen humuskolloidernas kemisk-fysikaliska egenskaper (aggregering, mängden och arten av funktionella grupper, katjon- och anjonbyteskapacitet, vätemättnadsgrad, elementärsammansättning, resistens mot mikrobiell nedbrytning m m), eller mikrobflorans och markfaunans sammansättning och aktivitet. Ur skogsproduktionssynpunkt kan gödslingens restverkan vara både positiv och negativ. En väsentlig värderingsgrund i sistnämnda hänseende är gödslingens inverkan på humusens förmåga att såväl binda som leverera växtnäring.

När det gäller engångsgödsling med givor, som användes inom det praktiska skogsbruket idag, torde det oftast vara förknippat med betydande mättekniska svårigheter att registrera de relativt små effekter på humusens mängd och egenskaper, som det i regel är frågan om. Icke minst ställs det härvid mycket höga krav på provtagningsmetodiken i fält. Den skogsekologiska forskningen har av det skälet varit tvungen att tillgripa försöksmodeller, där näringsämnena tillförs antingen i höga engångsgivor, eller också i måttliga doser, som upprepas efter korta tidsintervaller. Då en sådan appliceringsteknik högst avsevärt avviker från den, som tillämpas i praktiken, bör naturligtvis viss försiktighet iakttagas vid tolkning av resultaten från dylika försök.

I föreliggande rapport kommer det rubricerade frågekomplexet att belysas med resultat från pågående svenska, framför allt författarens egna undersökningar. Huvudvikten skall härvid läggas på markprocesser, vilka ingår i kvävecykeln.

Inverkan av kvävegödselmedel

I den fortsatta framställningen kommer det i olika sammanhang att hänvisas till ett kvävedoseringsförsök, som utlagts i ett avverkningsmoget tallbestånd i Västmanland (Kroksbo, 7404, Heby). Jordartsmaterialet på denna ståndort består av vattensediment, huvudsakligen sand, och jordmånen utgöres av järn-humuspodsol. Mårlagrets mäktighet är 3—5 cm, pH-värdet 3,9 och C/N-kvoten 39. Försöksplanen omfattar två kvävekällor (ammoniumnitrat och urea), tre kvävegivor (150, 300 och 600 kg N/ha), samt kontrolledet. Undersökning av marken har utförts vid tre olika tidpunkter: 3 månader, 1 år och 2 år efter gödslingens utförande. Försöket avser att belysa gödselkvävets omsättningar i marken samt eventuella förändringar i markens kemiska och biologiska egenskaper.

pH och basmättnadsgrad.

Enligt gängse uppfattning är korttidseffekten av ureagödsling en pH-höjning, både i förna och humuslagret. Initialeffekten av ammoniumnitratgödsling är däremot en pH-sänkning. Vid långtidsobservation finner man att markens pH ej påverkas signifikant av ureatillförsel, medan ammoniumnitratet kan ha en svagt acidifierande restverkan. Rent generellt tycks gälla att användningen av ammoniumhaltiga gödselmedel sänker basmättnadsgraden i humustäcket, medan nitratgödselmedel höjer den.

Förhållandet illustreras med resultat från Kroksbo-försöket, och avser läget ett år efter gödslingens utförande (fig. 1). Som synes har urean, men även de högsta givorna av ammoniumnitrat, höjt pH i humuslagret. Denna effekt hade starkt reducerats, när markundersökningen utfördes ett år senare. Med stor sannolikhet kommer den att försvinna helt, och eventuellt övergå till en svag pH-sänkning, i och med att marken tömts på restmängder av utbytbart NH_4. Ammoniumgödselmedlens och ureans acidifierande verkan förstärks sålunda med graden av kvävets tillgodogörande av vegetationen, inkl. mikrobfloran. Vad beträffar nitratbildningen torde även den förstärka amoniumkvävets acidifierande verkan på marken, speciellt under förhållanden, då en del av det bildade nitratet utlakas. Denitrifikationen uppvisar en motsatt verkan.

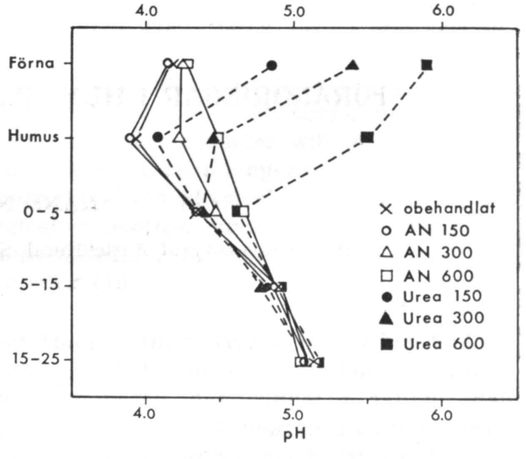

Fig. 1. Kroksbo, 7404. pH-värden i olika markhorisonter ett år efter gödselutspridningen.

Tabell 1. Utbytkart K i humuslagret Kroksbo, 7404. Markundersökningen genomförd ett år efter gödslingen.

Försöksled	Utbytbart K, me/100 g humus*)
Kontroll	1.96**)
Ammoniumnitrat 150	1.82
Ammoniumnitrat 300	1.62
Ammoniumnitrat 600	1.44
Urea 150	1.81
Urea 300	1.99
Urea 600	1.95
Standardavvikelse	0.14

*) korrigerat för mineraljordblandning.

**) motsvarande 31.9 kg K per hektar och skikt.

Utöver inverkan på pH och vätemättnadsgrad, kan man ofta spåra en viss verkan av kvävegödslingen på baskatjonsammansättningen hos utbyteskomplexet. På grund av ammoniumjonernas förträngande effekt leder gödslingen med ammoniumnitrat, i mindre grad även med urea, till ett visst utarmande av humuslagret på baskatjoner. Utlakningen drabbar i första hand katjoner som uppvisar en svag bindningsenergi på humuskolloiderna, dvs Na, K och i viss mån Mg. Förhållandet illustreras med data från Kroksboförsöket, som anger relationen mellan kvävedosering och förekomsten av utbytkart K i humuslagret (tabell 1).

Parentetiskt må nämnas att en hög ammoniummättnad, som kan bli följden av kraftig ureagödsling, ökar humuskolloidernas benägenhet till dispergering och vertikal transport i markprofilen.

Upplagring av kväve i markprofilen.

Med anlitande av ^{15}N-tekniken har man kunnat fastställa att en betydande del av gödselkvävet immobiliseras i marken och står sålunda att återfinna i markprofilens olika skikt i organiskt bunden form (Björkman et al. 1967, Nômmik och Popovic, 1971, Popovic och Nômmik, 1972). Vad beträffar gödselmedel som innehåller kvävet i form av ammonium eller urea, kompliceras tolkningen av immobiliseringsvärdena av kvävets mikrobiologiska turnovercykel i marken. En del av den uppmätta immobiliseringen torde sålunda vara apparent, dvs en produkt av undersökningsmetodiken. Den klassiska differensmetoden ger systematiskt lägre immobiliseringsvärden.

Med stöd av uppgifterna på totalkväveinnehåll och kvoten C/N har man på försöksfältet Kroksbo försökt att uppskatta omfattningen av gödselkvävets immobilisering i de olika markskikten (fig. 2). En sådan beräkning, som baserats på analysdata erhållna ett år efter gödslingens utförande, gav vid handen att av den lägsta ureagivan (150 kg N/ha) återfanns i den undersökta delen av markprofilen inte mindre än 60 % av kvävet i organiskt bunden form. Motsvarande siffra för ammoniumnitratet låg på 26 %. Noteras bör den höga immobiliseringen av ureakväve i humushorisonten, samt den med stigande kvävegivor avtagande procentuella immobiliseringen.

I detta sammanhang bör man ha det klart för sig att den undersökningsmetod, som här

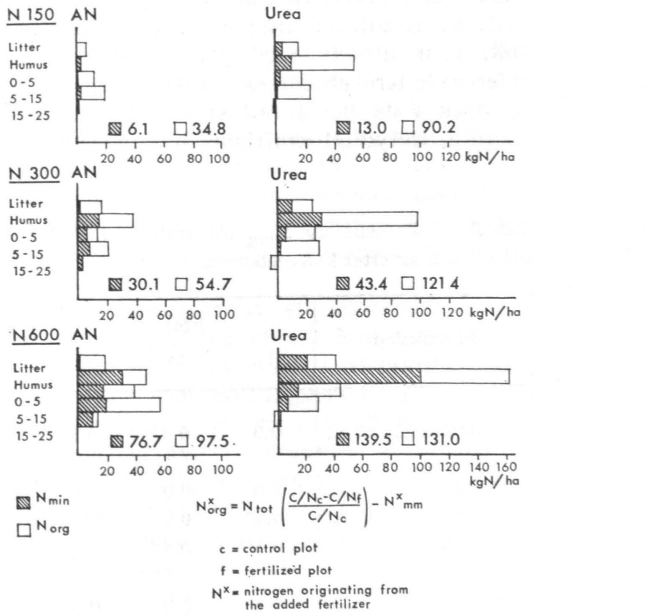

Fig. 2. Mängden gödselkväve återfunnen i markprofilen ett år efter gödslingens utförande. Kroksbo, 7404.

använts, ej möjliggör att skilja mellan kvävet i humus och avdöda växtrester, mikrobflora och mikrofauna och i växtrötter. Gödselkvävet, som ansamlats i växtrötterna, ingår sålunda till en del i de uppmätta immobiliseringsvärdena.

Vad beträffar immobiliseringskapaciteten för marker som tidigare gödslats med kväve, dvs vid en eventuell omgödsling, är informationen mycket knapphändig. Korttidsobservationer i lagringsförsök tycks tyda på att immobiliseringen av tillfört kväve blir något lägre i humusen som uttagits från ytor som tidigare behandlats med ammoniumnitrat eller urea (se fig. 4).

Mineralisering av humuskväve och kol.

Som ovan antytts resulterar kvävegödslingen i en viss anrikning av organiskt N i marken. Beroende på kvävekällan och humustäckets art och mäktighet synes engångsgödslingen med 150 kg N/ha kunna höja halten av organiskt bundet kväve i både förna- och humuslagret med upp till 10 %. Vilken restverkan detta har på mineraliseringsutflödet i marken är emellertid knappast utrett. Att restverkan kan vara positiv, ansyds av resultaten från ett inkubationsförtök, som utförts med jordar från ovan refererade Kroksboförsök (tabell 2). Utslagen är dock i de flesta fall statistiskt insignifikanta. Betydligt kraftigare utslag, vad beträffar mineraliseringsutflödet för kväve, har registrerats med jordar, som i fält årligen gödslats med stigande mängder kväve (se fig. 3).

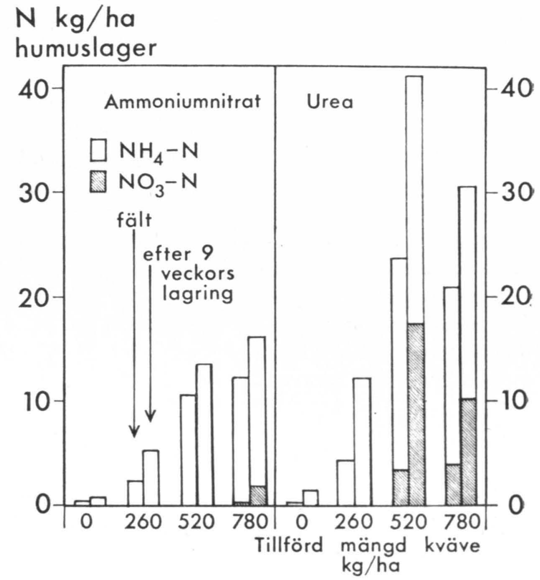

Fig. 3. Oorganiskt kväve (före och efter 9 veckors lagring) i humuslager efter tillförsel av olika total mängd kväve. Medeltal av 3 försöksparceller. Norrliden, Västerbotten. (Popovic, 1977, omarb. Wiklander, 1976).

Tabell 2. Procent av N$_{org}$ mineraliserad under 4, 8 resp. 16-veckors inkubation. Markprovtagningen utförd två år efter kvävegödselns utspridning. Block II. Krosbo, 7404.

Försöksled	Förna			Humus			Mineraljord 0–5 cm		
	4v	8v	16v	4v	8v	16v	4v	8v	16v
Kontroll	0.0	0.0	0.1	0.1	0.9	2.2	0.0	1.0	2.9
AN 150	0.0	0.0	0.0	0.1	0.3	0.9	0.0	0.7	3.1
AN 300	0.0	0.0	0.0	0.0	0.4	2.0	0.3	1.3	5.0
AN 600	−0.5	−0.5	−0.2	−0.2	−0.3	−0.3	0.5	1.9	4.6
Urea 150	0.0	0.0	0.3	1.6	3.2	3.0	0.0	0.4	1.6
Urea 300	−0.5	−0.5	−0.5	0.4	3.6	3.9	0.3	2.1	5.1
Urea 600	−2.2	−4.1	−4.0	−0.3	0.1	3.5	0.7	1.7	6.0

Standardavvikelse 1.2

Tabell 3. Mineralisering av kol under inkubation, promille av C$_{tot}$ per dygn. Kroksbo, 7404. Markprover uttagna två år efter kvävegödselns utspridning. Inkubationstemperatur 20° C. CO$_2$ avgivandet mätt under inkubationsperiodens 54–56 dygn.

Horisont	Kontroll	Ammoniumnitrat			Urea		
		150	300	600	150	300	600
Förna	1.55	1.66	1.61	1.36	1.56	1.24	1.29
Humus	0.89	0.76	0.65	0.51	0.77	0.58	0.55
Mineraljord 0–5 cm	0.86	0.80	0.74	0.74	0.80	0.94	0.80

Standardavvikelse 0.08

Vad beträffar kvävegödslingens inverkan på mineraliseringen av humuskol, kan viss information hämtas från inkubationsförsök, som citerats ovan. Mätvärden på CO$_2$-avgivande uppvisade i detta fall en trend att avtaga med stigande kvävegivor (tabell 3). Det kan förmodas att en dylik hämmande verkan är kortvarig och uppträder signifikativt enbart vid höga kvävedoseringar.

Nitrifikation.

Våra skogsmarker, med uteslutande av vissa brunjordar, kännetecknas av en mycket svag kapacitet att bilda nitrat. Efter vissa ingrepp i bestånds- eller markvårdande syfte kan emellertid en del av dessa marker bli nitrifierande. Bl a har detta konstaterats på marker, som har varit föremål för upprepad gödsling med urea fem år i följd (fig. 3, Popovic 1977). Liknande observationer har gjorts i humusprover, som uttagits från försöksytor, som tidigare behandlats med 600 kg N/ha och sedan omgödslats med en kraftig dos av urea (Kroksbo, 7404). Likaså har kalkningen av godartade mårhumusmarker inducerat, ofta på ett dramatiskt sätt, nitratblandningen i humuslagret.

Huruvida den gödslingsregim, som tillämpas inom det praktiska skogsbruket (omgödsling efter vart 5–10 år), kan framdriva nitratbildning på våra marker, vet vi ingenting med säkerhet idag (cf. Ehlert et al. 1974). Skulle detta ske blir det i första hand på marker med brunjordskaraktär.

»Priming effect».

Åtskilliga observationer tyder på att tillförseln av handelsgödselkväve har en positiv inverkan på mineraliseringen av markens eget kväve. Mekanismen bakom en sådan reaktion är inte helt klarlagd. En del författare, som studerat frågan med hjälp av ^{15}N-tekniken anser att fenomenet bara är en chimär, och beror på en feltolkning av den uppmätta isotoputspädningen, som föranletts av det biokemiska utbytet mellan märkt gödselkväve och omärkt humuskväve. Andra författare däremot har funnit att denna »priming effect» är reell, och en konsekvens av den höga saltkoncentrationen på mikro-organismerna (partiell sterilisering) eller också på humusens kolloidkemiska egenskaper.

Våra egna undersökningar synes stödja den sistnämnda uppfattningen, även om reaktionens praktiska betydelse får betecknas som oklar. Effekten kommer tydligast fram vid gödsling av mårhumusmark med nitrat, och den yttrar sig i en excessiv ansamling av ammoniumkväve (Nômmik, 1968, Nômmik och Popovic, 1971, Popovic och Nômmik, 1972).

En uppfattning av storleken och arten av denna »priming effect» kan man få av resultat, som framkommit i ett inkubationsförsök, och som åskådliggörs i fig. 4. Skillnaden mellan återfunna och tillförda mängder gödselkväve i oorganisk form har i detta fall tagits som mått på storleken av »priming effect». Ett negativt tecken på »priming effect» anger att immobiliseringen av gödselkväve har varit större än den av gödslingen inducerade mineraliseringen av markens eget kväve.

En tydlig positiv »priming effect» observeras för ammoniumnitrattillsatser, vilken för en gödselgiva av 150 kg N/ha, kan upp-

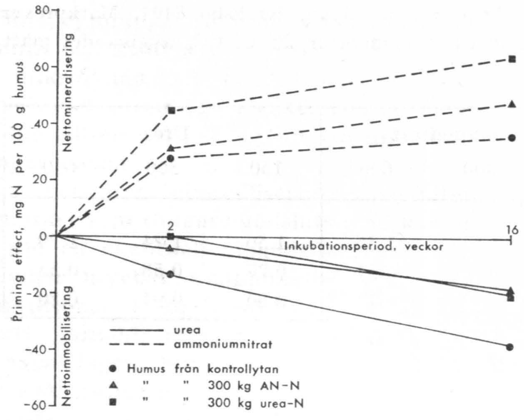

Fig. 4. »Priming effect» för tillfört ammoniumnitrat resp. urea Dosering: 132 mg N/100 g humus (Kroksbo, 7404).

skattas till 40–60 mg NH_4-N per 100 g humus. Räknat per hektar och skikt (50 ton humus) skulle detta motsvara till 20–30 kg N.

Vid ureagödsling överskuggas mineraliseringstillskottet av en kraftig immobilisering, varför »priming effect» blir negativ.

Gödsling med fosfor och kalium.

Förändringar i humuslagret efter fosfor- och kaliumgödsling har ej varit föremål för lika omfattande studier som efter kvävetillförsel. Man kan förutsätta att en viss påverkan sker, och då i första hand beträffande jonsammansättningen hos markens utbyteskomplex. Surhetsgraden torde knappast påverkas av en måttlig tillförsel av superfosfat eller kalisalt. Användning av råfosfat torde däremot medföra en förskjutning av markens pH i riktning mot neutralpunkten. Dessutom kan man förvänta sig en viss biologisk fastläggning av tillförd fosfor i marken, med konsekvensen att halten P_{org} ökar. Denna synes kunna förstärkas genom ureagödsling med följden att markens förmåga att leverera lättassimilerbar fosfor försämrades.

I likhet med kvävegödselmedel synes tillförseln av lättlösliga fosfor- och kaliumsalter medföra vissa osmotiska effekter, vilka yttrar sig bl a i nedsatt hastighet för både kolmineralisering, kväveimmobilisering och denitrifikation. Beträffande mineraliseringen av markens kväve tycks effekten däremot bli positiv. Det extra tillskottet för mineraliseringsutflödet, som därvid uppstår, torde dock bli ganska litet och knappast överstiga 10 kg N per hektar. Denna indirekta kväveverkan av fosfor- och kaliumhaltiga gödselmedel kan dock i vissa fall vara av sådan storleksordning att en mätbar tillväxtreaktion ej kan uteslutas.

Högst dramatiska förändringar i mårhumusens egenskaper kan åstadkommas med kalkning. Effekterna av en dylik markförbättrande åtgärd står dock utanför ramen av denna framställning.

Sammanfattning

Skogsgödsling på fastmarker, speciellt vid hög näringsämnesdosering eller vid omgödsling efter korta tidsintervaller, synes kunna leda till mätbara förändringar i humustäcket. Påverkan kan gälla både humusens sammansättning och kolloidkemiska egenskaper, och mikrobflorans och mikrofaunans aktivitet i humuslagret. Ur produktionssynpunkt kan dessa förändringar vara både positiva och negativa.

Vad beträffar humusens pH och vätemättnadsgrad påverkas de ej signifikant av en konventionell kvävegödsling. Upprepad användning av ammoniumnitrat kan dock bidraga till markens acidifiering och till dennas utarmning på utbytbara baskatjoner, i första hand kalium och magnesium. Kvävegödslingen, i synnerhet med urea, resulterar i en upplagring av organiskt bundet kväve i marken. Detta synes höja mineraliseringsutflödet för kväve under åren närmast efter gödslingens utförande. Ureagödsling synes även höja markens förmåga att bilda nitrat. Gödsling med såväl ammoniumnitrat som med lättlösliga kalium- och fosforgödselmedel tycks kortvarigt kunna öka mineraliseringen av markens eget kväve. Mineraliseringshastigheten för humuskol kan däremot bli något nedsatt.

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BALANSERAD NÄRINGSUPPTAGNING OCH BEHOVET AV GÖDSLING I TRÄDBESTÅND PÅ NÄRINGSFATTIGA TORVMARKER

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Sammandrag av anförande*

I anförandet behandlas behovet av gödslingsåtgärder vid virkesproduktion på näringsfattiga torvmarker varmed avses sådana torvmarker där beståndstillväxten efter en tillfredsställande dränering kan ökas genom tillförsel av ett eller flera näringsämnen.

Utgående från att de högre växterna, för att utvecklas normalt, enligt idag gällande uppfattning, fordrar sexton olika grundämnen konstaterades, att dess grundämnen vid balanserad näringsupptagning bör finnas tillgängliga i växtunderlaget i bestämda proportioner. Sålunda bör växten för varje molybdenatom uppta 100 kopparatomer, 300 sinkatomer osv. Denna såkallade balanserade näringsupptagningen kan dock icke anses som en statisk process utan mera som ett dynamiskt skeende, vilket är beroende av såväl genetiska faktorer som växtart och dess utvecklingsskede.

Behovet att tillföra ett eller flera näringsämnen vid virkesproduktion på torvmarker kan bestämmas genom att undersöka mängden näringsämnen som fastlagts i biomassan och tillgången till motsvarande näringsämnen i växtunderlaget. Ett dylikt granskningssätt, vilket ur ekologisk synvikel är ofullständigt, ger för handen, att fosfor och kalium är minimumfaktorer då det gäller tallbestånd på näringsfattiga torvmarker av såväl ombrogen som soligen typ. Dessutom är kväve en tillväxtbegränsande faktor på de kvävefattigare soligena torvmarkerna och på samtliga ombrogena torvmarker. Det får vidare hållas för sannolikt, att bor tillgången redan under ett tidigt skede av beståndutvecklingen är underoptimal. Eventuellt kommer också koppar och mangan att utgöra tillväxtbegränsande faktorer i ett senare skede av beståndsutvecklingen. Dessa förhållanden gäller givetvis under förutsättningen, att mikronäringsämnenas löslighet i torven inte förändras genom t.ex. en pH förskjutning.

De här presenterade sambanden har i Norge experimentiellt kunnat verifieras i plantbestånd för omloppstidens första tjugo år. De på torvmarker utförda försöken har varit minusförsök med ett sammansatt göd-

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* The compleat paper will published in the journal Suo vol. 28,3.

selmedel från vilket i tur och ordning utelämnats något av de för plantornas utveckling nödvändiga näringsämnena.

I anförandet diskuterades vidare tillväxtstörningar i de undersökta plantbestånden. Omfattande toppskottsskador hade observerats i de försöksled från vilka utelämnats koppar och bor. Skadan yttrade sig sålunda att terminalskotten hos isynnerhet tall och gran torkade innan de nått full utvecklingsgrad. Ett karakteristiskt drag är också, att bildningen av adventivknoppar vid basen av de skadade skotten sker långsamt, vilket medför att lång tid åtgår innan skadan reparerats. Toppskottet hos träd utan synliga skador uppvisar en karakteristisk spiralväxt.

Den utlösande orsaken till dessa observerade omfattande skador antogs vara en i torven sent liggande tjäle, som resulterat i ett vattenunderskott i de vegeterande plantorna. Detta skeende är förenligt med verkningsmekanismen för borbrist.

Analyser av barrmaterial från de skadade träden visade entydigt på ett lågt bor innehåll i barren. Det konstaterades dock, att ett lågt innehåll av bor i och för sig inte behöver vara skadligt, men att ett sådant tillstånd kan nedsätta plantans motståndskraft mot t.ex. just vattenbrist.

EFFECT OF FERTILIZATION ON NUTRIENT CONTENTS IN NEEDLES AND LITTER FALL OF SCOTS PINE ON DWARF SHRUB PINE SWAMP.

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Introduction

Until quite recently fertilization investigations on peat soils have focused on how the volume growth of forests, i.e. the yield of wood, is affected by fertilization. Although important for practical fertilization activities, such information alone create an incomplete notion of the fertilization effect on the entire ecosystem. Consequently, additional factors related to nutrient cycle either directly or indirectly have to be investigated as well as the changes brought about by fertilization.

In the spring of 1974 the Department of Peatland Forestry at the Finnish Forest Research Institute set up a series of experimental plots at Jaakkoinsuo in Vilppula (62° 04'N, 24° 34'E) to investigate the effect of fertilization on nutrient cycle on a dwarf shrub pine swamp. As this peatland type is known for its usually short fertilization effect (e.g. HUIKARI & PAAVILAINEN 1972, KARSISTO 1972, 1974, PAAVILAINEN 1972, 1974), the investigation included experimental plots with both basic fertilization and refertilization. Several factors related to nutrient cycle were measured. This report is concerned with the results acquired so far of the effect of fertilization on the nutrient contents in needles and litter fall of pine.

Table 1. Tree stands on experimental plots in May, 1974.

Fertilization in 1965	No refertilization			NPK fertilization in 1974		
	m^3/ha	m^2/ha	Stems/ha	m^3/ha	m^2/ha	Stems/ha
O	116,3	16,6	688	99,0	13,7	592
PK	78,6	13,1	800	91,8	14,0	757
NPK	114,9	16,1	784	95,1	14,3	784

Table 2. Peat pH and nutrient content in November, 1976.

Fertilization in 1965	No refertilization					NPK fertilization in 1974				
	pH	N, %	P, mg/l	K, mg/l	Ca, mg/l	pH	N, %	P, mg/l	K, mg/l	Ca, mg/l
O	3,3	1,32	202	85	641	3,3	1,34	178	87	682
PK	3,3	1,20	175	84	593	3,1	1,15	195	78	779
NPK	3,2	1,26	168	77	467	3,3	1,15	130	68	486

Layout of the experiment

There are six experimental plots, four of which measure 25 × 25 m and two 25 × 28 m. Information pertaining to tree stands are presented in Table 1 and the pH and nutrient content of peat in Table 2.

Ground vegetation was largely formed of dwarf shrubs, as can be seen in Table 3.

Eight measuring funnels with a mouth area of 0.5 m^2 were placed on each experimental plot for collecting litter. Litter samples were gathered once a week June through November in 1974 and afterwards at least once a month excluding February—March in 1976, when litter fallen during the first part of the year was collected in April.

The following fertilization treatments were included:

Number of plot	Fertilization June 2, 1965	Fertilization June 5, 1974
1	–	–
2	–	NPK
3	NPK	–
4	NPK	NPK
5	PK	–
6	PK	NPK

Table 3. Dominance and biomass of the most important species in ground and field layers on two plots in August, 1974 (see KOSONEN 1976).

Plant species	Sample plot 1 Unfertilized		Sample plot 3 NPK fertilization in 1965	
	Dominance %	Biomass g/m^2	Dominance %	Biomass g/m^2
Field layer				
Andromeda polifolia	–	–	1	2,5
Calluna vulgaris	–	–	1	35,1
Empetrum nigrum	13	24,6	5	6,2
Ledum palustre	39	167,6	43	246,3
Vaccinium myrtillus	12	20,9	7	13,1
Vaccinium uliginosum	3	5,5	4	7,4
Vaccinium vitis-idaea	24	62,8	11	28,6
Eriophorum vaginatum	5	2,0	3	1,5
Rubus chamemorus	1	1,0	17	7,3
Ground layer				
Dicranum spp.	3	10,0	+	–
Pleurozium Schreberi	56	13,9	61	17,0
Sphagnum angustifolium	28	8,6	23	20,6

Table 4. Nutrient content of needles in percentage from dry matter in March, 1977.

Fertilization in 1965	No refertilization					NPK fertilization in 1974				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
0	1,60	0,145	0,549	0,261	0,115	1,60	0,169	0,538	0,293	0,132
PK	1,48	0,164	0,577	0,261	0,125	1,46	0,169	0,554	0,293	0,134
NPK	1,57	0,163	0,571	0,235	0,114	1,57	0,176	0,527	0,242	0,132

In 1965: PK = 600 kg/ha PK fertilizer (16,5 % P_2O_5 — 16,5 % K_2O)
: NPK = 550 kg/ha NPK fertilizer (14 % N — 18 % P_2O_5 — 10 % K_2O).
In 1974: NPK = 400 kg/ha Oulu saltpetre (26 % N) + 500 kg/ha PK fertilizer (24 % P_2O_5 — 15 % K_2O).

Growth and nutritional status of tree stand

The effect of the first fertilization in 1965 on the growth of the tree stand was almost completely terminated. Without refertilization the growth of the basal area of the tree stand was only slightly better on NPK fertilized than on unfertilized control plot (Fig. 1).

NPK refertilization in 1974 clearly increased the growth of the tree stand. In 1974—1976 the effect of refertilization was the most prominent on the experimental plot with PK fertilization in 1965.

Needle samples taken in March, 1977, were analysed for the main nutrients and certain micronutrients. As to the main nutrients, the effect of the first fertilization was still apparent in the phosphorus and potassium contents of needles (Table 4). These contents were higher on fertilized than unfertilized plots. The 1974 refertilization seems to have increased the phosphorus, calcium und magnesium contents of needles.

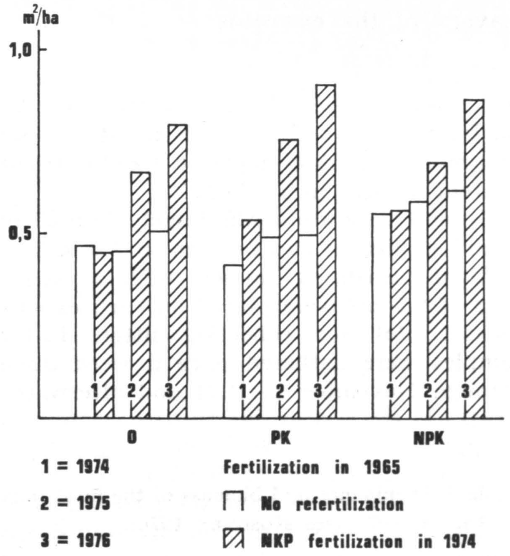

Fig. 1. Growth of basal area of tree stand.

Table 5. Nutrient content of needles at different ages in percentage from dry matter June 5—6, 1977.

Fertilization in the year 1965	1974	Nitrogen (N) 1974	1975	1976	Phosphorus (P) 1974	1975	1976	Potassium (K) 1974	1975	1976	Calcium (Ca) 1974	1975	1976
0	0	1,43	1,48	1,73	0,10	0,11	0,11	0,33	0,34	0,36	0,32	0,30	0,23
PK	0	1,06	1,12	1,06	0,09	0,10	0,10	0,28	0,33	0,33	0,65	0,50	0,33
PK	NPK	1,32	1,34	1,12	0,11	0,12	0,11	0,33	0,37	0,47	0,61	0,56	0,37

Table 6. Micronutrient content of needles (ppm) in March, 1977.

Fertilization in 1965	No refertilization				NPK fertilization in 1974			
	Mn	B	Cu	Zn	Mn	B	Cu	Zn
0	243	18,4	1,42	37,6	290	18,4	1,25	57,5
PK	225	12,8	1,33	50,9	275	13,6	1,07	46,5
NPK	225	13,6	1,25	44,2	240	16,0	0,89	48,7

At the beginning of June in 1977 still three additional plots were sampled and the contents of the main nutrients determined of needles with different ages (Table 5). When comparing the results of 1976 needles to those presented in Table 4, it is seen that the nitrogen, phosphorus and potassium contents of needles had decreased between March and June (cf. e.g. TAMM 1955). The nutrient contents of needles taken in June, during a vigorous growth season, show that there was less nitrogen and phosphorus on plots fertilized with PK in 1965 than on control plots, almost equal amounts of potassium but more calcium especially in the 1974 needles. NPK refertilization increased somewhat the P and K contents of needles, although the N content was still lower than on unfertilized control plots. The needle analysis in June indicated better than the one carried out in March the need for refertilization on previously PK fertilized plots.

Difference between various treatments are not great as regards micronutrients (Table 6). The most distinct tendency is observed in the copper content of needles, which appears to diminish under the influence of both basic and refertilization.

The 1974 refertilized had a prominent effect both on parts above ground and on the amount of nutrient-taking roots of pine. The following table shows how the amount of thin pine roots increased after refertilization, while the amount of roots of ground vegetation remained the same.

	No refertilization	NPK refertilization in 1974
Pine roots, m/m²	1692	2551
Roots of ground vegetation, m/m²	1302	1263

Thus fertilization intensified the nutrient uptake of pine as compared to that of ground vegetation.

Litter and its nutrient content

Difficulties in comparing various fertilization treatments arise, because there are differences in the amount of pine litter due to e.g. differences in the wood volume of the stand and number of trees in various plots. It is, however, obvious that NPK fertilization carried out in 1974 considerably increased litter fall as early as the summer and autumn of the following year (Fig. 2). The largest increase, i.e. about 1300 kg/ha/y., occurred on plots fertilized with PK in 1965. Increase in litter fall caused by fertilization

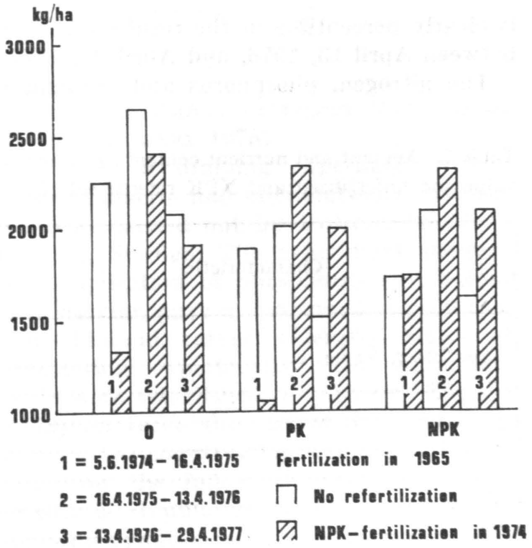

Fig. 2. Amount of litter fall.

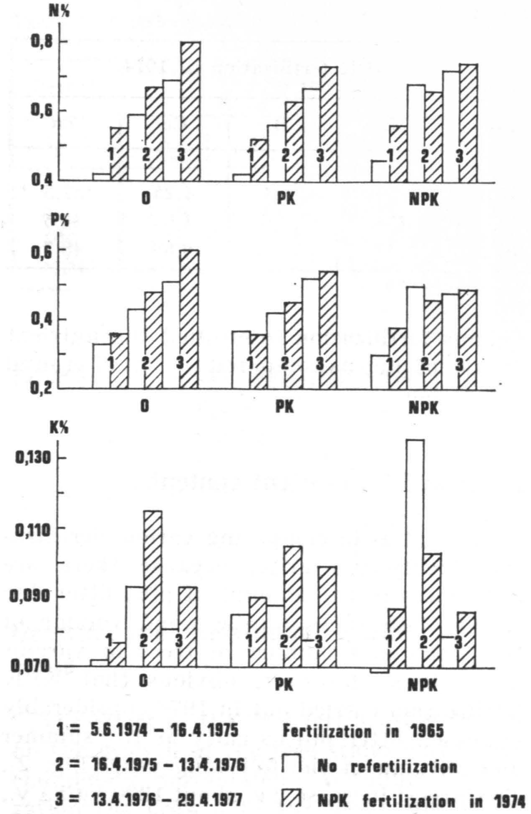

Fig. 3. Nutrient content of litter weighted with dry weight.

is clearly perceptible in the results received between April 13, 1976, and April 29, 1977.

The nitrogen, phosphorus and potassium contents weighted with the dry weight of litter were free from the 1965 fertilization effect (Fig. 3). Refertilization in 1974 increased nutrient contents. NPK refertilization seems, however, to have diminished the nitrogen, phosphorus and especially potassium contents of litter between April 16, 1975, and April 13, 1976, on the plot which received NPK- treatment also at the first fertilization, although a corresponding difference cannot be seen in the results from the period of April 13, 1976 — April 29, 1977.

Owing to a larger amount and higher nutrient content, pine litter contained more nutrients on plots refertilized in 1974 than on unrefertilized plots. The differences in nutrient amounts were, however, slight (Table 7). During one year of investigation (October 15, 1975 — October 14, 1976) litter fall had provided the refertilized plots with about 2,2 kg of nitrogen, 128 g of phosphorus, 379 g of potassium, a. 1,5 kg of calcium and 219 g of magnesium more than unrefertilized plots.

Final review

According to the results the effect of both PK and NPK fertilization on the growth of pine on a dwarf shrub pine bog has terminated in 9 years almost entirely. NPK fertilization at this point produced an increase in the nutrient contents of needles and improved the growth of the stand.

Table 7. Amount and nutrient content of litter between October 15, 1975 and October 14, 1976, as mean values on unfertilized and NPK refertilized plots.

Characterictic	Fertilization in 1974		Difference
	0	NPK	(NPK—0)
Tree litter, kg/ha	1658	1847	189
N, g/ha	11126	13320	2194
P, »	764	892	128
K, »	1308	1705	397
Ca, »	7335	8824	1489
Mg, »	850	1069	219
Mn, »	602	745	143
B, »	15,6	16,1	0,5
Cu, »	9,3	10,1	0,8

Similarly, the amount and nutrient content of litter increased. Yet, a very small part of the nutrients applied at refertilization returned among litter to the cycle during the first three years. Growth in nitrogen content of litter brought about by refertilization corresponded to a. 3,5 %, that of phosphorus to 0,3 % and that of potassium to 0,6 % of the applied nutrient amounts.

The results, although only the first preliminary ones, imply that the nutrients of tree litter returning to the ground are of slight importance as regards the utilization of nutrients by pine after refertilization on a dwarf shrub pine swamp. This applies particularly to phosphorus and potassium, the most important nutrients in connection with forest fertilization of peat soils.

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MICRO-NUTRIENT DEFICIENCIES CAUSE GROWTH-DISTURBANCES IN TREES

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Already at the beginning of this century the results of experimental forest-drainage and fertilization showed, that such activities should be concentrated on nutrient-rich peatland sites with shallow peat and natural tree cover. Limed and sanded fields, which are later manured, treated with Thomasphosphate or wood-ash proved to be productive sites, too. The experiences were parallel to those gained in Denmark, Norway, Sweden and Finland.

In Finland rather extensive experiments were also established on originally woodless peatlands. Afforestation developed well for the first 10—20 years after sowing or planting but subsequently the trees started to become stunted or even to die off. Fertilization with phosphorus and potassium caused the stunted stands to regain their initial vigour (Huikari 1973).

In 1950 a draining experiment which included macro- and micronutrient fertilization was carried out by Romell in West-Bothnia, Sweden. The experiment showed, that application of phosphorus and boron, in particular, gave a clear positive response.

In Finland rather extensive series of fertilization experiments with micro-nutrients were established in 1950 by Huikari (1973) on three sites situated in different parts of the country. The experiments were based on the following idea: when tree-growth is stimulated by draining and by applying macro-nutrients to sites originally poor in nutrients, it is probable that sooner or later a shortage of micronutrients will become a factor limiting tree-growth, too. As a results of mechanisation forest drainage activities were expanded already in the late 1950's and especially in 1960's. At the same time fertilization of the drained areas with nitrogen, phosphorus and potassium was begun. Consequently, treeless sites originally poor in nutrients became objects of forest drainage. At the end of the 1950's ploughing of mineral soils in forestry came into use instead of prescribed burning. One further characteristic of this development should be pointed out: the production of planting material was carried out more and more using growth-peat substrates (so called agricultural peat), which is physically favourable but extremely poor in nutrients. Thus, during the last decades a lot of plantations and young forests have grown up in which micro-nutrient deficiencies in the form of growth-disturbances will inevitably appear. A tendency toward the harvesting of total tree-biomass nowadays makes the problem more severe.

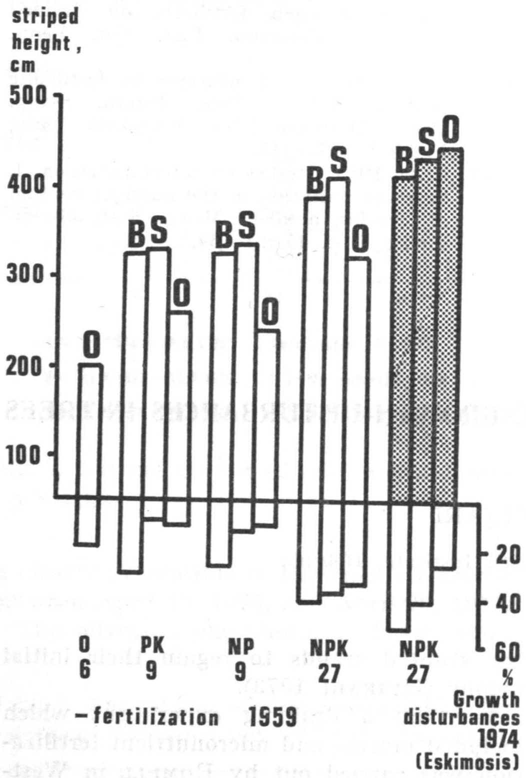

Fig. 1. Height of the pine stand and occurrence of growth-disturbances in 1974 at exp. I and V. Kivisuo (Veijalainen 1975).
First fertilization 1959:
Broadcast fertilization
(white pillars)
Spot fertilization
(dotted pillars)
Refertilization 1968:
B = Broadcast (PK 500 kg/ha)
S = Spot (PK 500 kg/ha)
O = Control

Growth-disturbances

For a long time certain abnormalities have occurred in the leader-growth of pines on drained sedge-rich open swamps with rimpis (wet depressions). As such growth-disturbances have become more common during the last few years even on very usual drainage, fertilization and melioration areas, systematic description and classification, as well as causal analysis concerning the phenomenon was started.

The name »eskimosis» was casually given to the syndrome in question. A typical feature of the symptom sequence seems to be the destruction of apical buds and shoots. The phenomenon is most evident in well-growing stands. Usually the pattern has clear boundaries, which follow, for example, the depressions of the peat surface (rimpis). Such phenomena have been found both on mineral and peat soils with or without fertilization. The emergence of the disturbances seems to be dependent on the amount of cell material (plant-biomass) produced on the site in question (see fig. 1). The results from experimental strip width — series support this conclusion (fig. 2). The figure shows that the disturbances first appear in fast-growing trees on narrow strips and later on broader strips because the trees reach the definitive cell material limit at a later stage. It is clear that the phenomenon can be a source of systematic error in productivity studies, and when conclusions, for instance, about the effectiveness of drainage, are made on the basis of material collected from older ditching areas. The syndrome occurs in rather a similar way in Scots pine, Norway spruce, birch, aspen, alder-species and willow-species, i.e. probably in all tree-species.

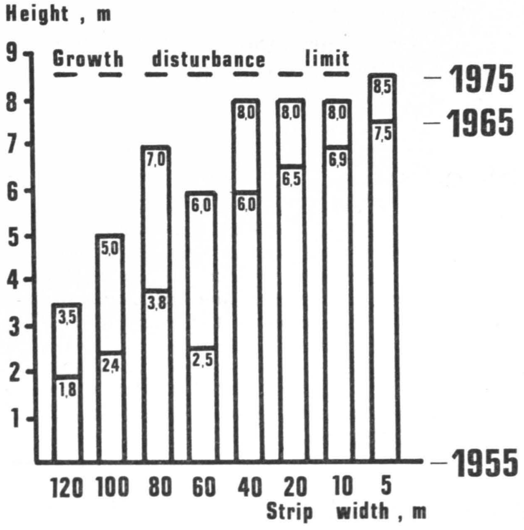

Fig. 2. Height development of Scots pine at Sotkamo. Drained in 1954.

Many problems have come up in the research work. It is clear that the field experiments are not able to give visual or measurable answers to this question if the micro-nutrients are an ultimate minimum factor before the stand has exhausted the micro-nutrient reserves of the site. This process can take several decades. At the same time some other growth factor can change and become the minimum factor, and thus, prevent information about the micro-nutrients being obtained.

Since the phenomenon is horizontally sharply restricted within the site, mixed samples cannot be used in chemical soil analyses, but each sub-sample must be analysed separately or the density of samples must be adapted according to the site figures. This concerns plant-tissue analyses, too.

When needle or leaf analyses are carried out it must be taken into account that a phenomenon called dilution of nutrients (»Verdünnungseffekt») makes the interpretation of analyses more diffcult and, in the worst case, surely leads to erroneous conclusions. This is due to the fact that a sample cannot be taken of the cells and plants which are not produced owing to micro-nutrient deficiency.

Research activities started in Finland

During the last few years research work with a definite aim has been started. The goal is to clarify the possibilities of identifying, analysing and preventing such growth-disturbances. The research work has involved seven scientists working under the leadership of the author. The working plan is very many-sided and exactly defined. In 1977 the project will use mk 400 000,— but the finances even in the near future are still quite open.

The most important results of the research project are as follows:

1. The phenomenon is defined so that identification can be carried out without confusion with diseases or damage caused by fungi or animals, macro-nutrient deficiencies, unfavourable water conditions or mechanical factors.
2. The occurrence and distribution of the phenomenon is mapped; there are about 300 severe cases with a total area of nearly 3000 ha. The disturbances are distributed on peat and mineral soils both on fertilized and unfertilized sites. Treatment with macro-nutrients increases the risk of the syndrome appearing both as a result of the growth increase and the reduction in micro-nutrient concentrations.
3. The phenomenon is known to occur in many tree species but not in monocotyledons.
4. There are also hidden disturbances, i.e. anatomical cellanomalies (cavities in the parenchyma etc.) are found in trees which are otherwise apparently normal. These are found in the buds, leaves (needles) and roots.
5. Some micro-nutrient concentrations in the needles and roots of the disturbed trees are lower than those in healthy trees (fig. 3). Boron deficiency seems to be most common. In the growing points and young shoots of disturbed trees the acidity of the cell-sap is higher than that of normal trees.
6. The growth-disturbances can be corrected and growth will return to normal 2—3 years after fertilization with woodash. Positive responses with micro-nutrient

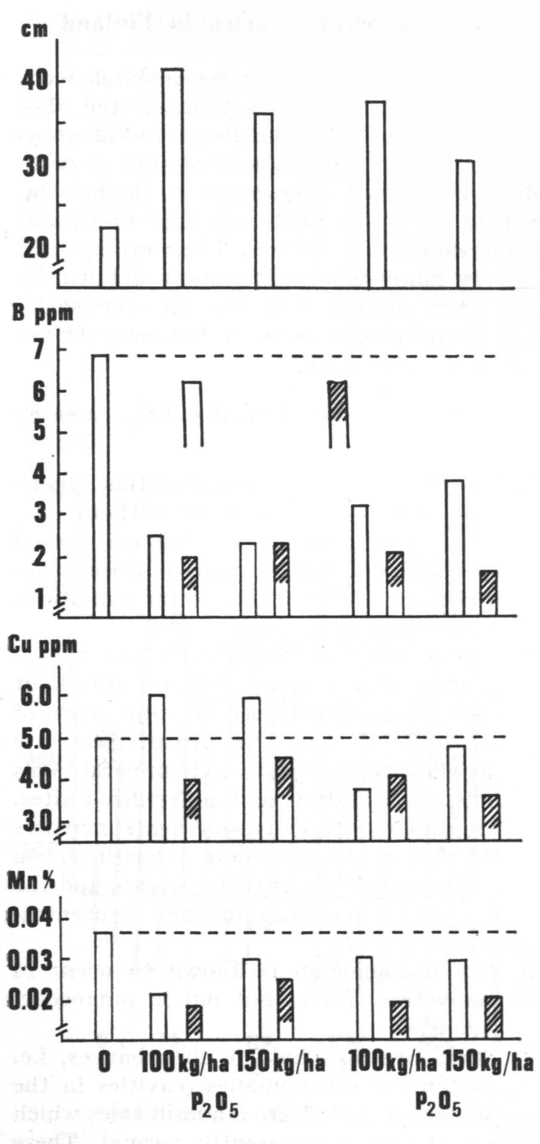

Fig. 3. Height growth of Scot pine and boron, copper and manganese concentration in needles nine growing periods after fertilization on a top sedge pine swamp at Rautavaara. White pillars: apical shoots normal, striped pillars: growth-disturbances in apical shoots.

fertilizers are obtained, too, although practical instructions for the use of micro-nutrient fertilizers have not yet been developed. It is possible that the best responses will be obtained by giving micro-fertilization together with liming.

7. It is obvious, that micro-nutrient deficiencies in forests are more common and more widely distributed than has been imagined.

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Raitio, H. & Rantala, E.-M. 1977. Männyn kasvuhäiriön makro- ja mikroskooppisia oireita. Summary: The macro- and microsymptoms of a growth disturbance of Scots pine. Commun. Inst. Forest. Fenn. 91.1: 1—30.

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Veijalainen, H. 1974. Makro- ja mikrolannoituskoe kuusen »eskimosis»-alueella. Manuscript, Dep. of Peatland Forestry.

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TALLARNAS VÄXTSTÖRNINGAR, MARKENS NÄRINGSBALANS OCH MIKRONÄRINGSBRIST

HANNU RAITIO

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Inledning

Trädens morfologiska och anatomiska struktur på torv- och fastmarker i naturtillstånd är nästan alltid normal — frisk, eftersom de har anpassat sig till de där rådande, välbalanserade växtförhållandena. Produktionen är ändå inte alltid maximal, eftersom en eller flera av de ekologiska fakrorerna kan vara minimumfaktorer. Förutom vattenhushållningen är markens näringstillstånd ofta minimunfaktor på torvmarker i naturtillstånd. Så gott som utan undantag är det då fråga om låg tillgång till mikronäringsämnen. Genom att gödsla med makronäringsämnen — oftast NPK — får man en större produktion. Det är självklart, att då man gödslar endast med ett eller flera makronäringsämnen, rubbar man mer eller mindre markens näringsbalans beroende på utgångstillståndet. I praktisk skogsgödsling sprider man inte med avsikt så mycket gödsel, att gödseln skulle verka menligt, som gift, på träden. I praktiken har det dock visat sig, att en ensidig gödsling kan förorsaka tillväxtstörningen. Sålunda har en ensidig gödsling, eftersom det inte är fråga om giftverkan, förorsakat brist på något eller några växtnärinsämnen. Enligt Huikari (1974) är orsaken till trädens växtstörningar en mikronäringsbrist.

Bristen på något eller några näringsämnen kan uppstå på tre olika sätt: 1) den absoluta mängden av något ämne är för liten, 2) tillförseln av ett ämne kan verka antagonistiskt på ett annat, som det sedan blir brist på och 3) tillförseln av ett ämne kan åstadkomma en ökning i produktionen och härav följer, att det blir brist på ett annat (t ex. Bussler 1974).

Näringsbrist i växter kan uppträda på tre olika nivåer: 1) på den fysiologiska nivån, då bristsymptom kan observeras som kemiska och fysiologiska förändringar, 2) på den anatomiska nivån, då symptom observeras som anatomiska förändringar och 3) på den morfologiska nivån, då bristsymptom obseveras både som morfologiska och anatomiska förändringar (t ex. Bussler 1974).

En störd näringsbalans i marken kan verka både indirekt och direkt. Det är självklart, att en växt, som växer på ett växtunderlag med störd näringsbalans, också är ömtålig för många yttre faktorer, t ex. frost, skadeinsekter o.s.v. Yttre faktorer förorsakar ofta redan under störningens fysiologiska nivå yttre symptom. Däremot kan direkta symptom på störd näringsbalans observears först på den morfologiska nivån. Då störningstillståndet, som förorsakas av den rubbade näringsbalansen, förvärras, blir de störda växterna ömtåligare för de indirekta — yttre — faktorernas verkan.

Tallarnas växtstörningssymptom

Morfologiska symptom

Om våren — med andra ord som första symptom — kan man se störningar i tallens knoppbalans. Friska tallar präglas av. sk. apikaldominans, d.v.s. tallarna har en dominerande (ledande) terminalknopp och flere axillärknoppar. Sjuka träd har ofta störd knoppbalans. Terminalknoppen kan vara mindre än en eller flere axillärknoppar (»sidoknoppar»), och i sådana fall blir terminalskottet kortare än axillär (»sido-») skotten. Höjdskillnaden mellan ledande axillärskott och terminalskott kan, beroende på den rådande knoppbalansen även bli mycket liten. Om knopparna är likvärdiga, får trädet i regel flere likvärdiga toppar. Om våren kan trädet även ha två dominerande terminalknoppar; resultatet blir tvådelade toppar. Toppskottet kan också bli helt utan knoppar; även kan nästan alla knoppar ha dött.

En av de första växtstörningssymptomen är också att terminalskottet förgrenas i två eller flera delar. Förgreningsstället kan vara var som helst på skottet.

Knopparnas död, och störd knoppbalans i allmänhet, förorsakar stark knoppbildning i bl.a. kortskottens meristematiska spets, som vid normal utveckling dör. Den starka knoppbildningen förorsakar ett gytter; trädet har många toppar.

Störningar i knoppbalansen är alltså en symptomgrupp. Den andra gruppen är skottets utvecklingsstörningar. Knopparnas tillväxt och på så sätt utvecklingen av skott och barr börjar som vanligt — normalt — på våren, men plötsligt stannar utvecklingen under vegetationsperioden. På så sätt uppstår olika grader av utvecklingstörning i skotten och barren.

Den tredje morfologiska symptomgruppen är olika tofsbildningar. En tofs bildas, när avstånden mellan kortskotten blir kortare än vanligt. Tofsbildningar kan förekomma var som helst i skottet, t.o.m. kan hela skottet bilda en tofs.

Ganska ofta kan man se fasciation, mindre ofta att skotten rämnar. Kraftigt kådflöde i knopparna är också typiskt för störda träd.

Barrformen kan variera starkt; i allmänhet är de vid störningar i förhållande till sin längd oproportionerligt tjocka; krokiga; spiralformade; (t ex. Raitio & Rantala 1977).

Anatomiska symptom

Störd cellordning i vävnaderna och ihålig märg och knoppar är typiskt för ett sjukt skott. Det sjuka skottets döda knoppar ser bruna ut i ett längdsnitt. Ofta har märgen bruna fläckar, hela märgen kan t.o.m. vara brun och död.

I det friska barret är sklerenkymväggarna tjocka och lumen mycket liten. Ett av växtstörningens första anatomiska symptom är just att sklerenkymväggarna blir tunnare och lumen blir större. När störningen förvärras, bildas en hålighet i barrets mitt. Största delen av transfusionvävnaden kan vara ihålig, d.v.s. transporten av olika ämnen från ledningssträngen till mesofyllen och omvänt har delvis förhindrats. Hypertrofi i cellerna samt störningar i ledningssträngarna är också vanligt (t ex. Raitio & Rantala 1977).

Rötterna har man undersökt mycket litet. Om morfologiska symptom kan man ännu inte säga någonting. Man har gjort några tvärsnitt av ettåriga långrötter.

I långrötter har man också funnit ett av de första anatomiska symptomen: cellernas hypertrofi, särskilt i primärfloemet. Då störningen förvärras, uppstår även ihåligheter i primärfloemet och -xylemet före bildning av sekundärfloem och -xylem; d.v.s. transporten av olika ämnen har åtminstone delvis försvårats även i rötterna (t ex. Kolari, Paavilainen & Raitio 1977).

Diskussion

På grund av de morfologiska och anatomiska symptomen kan man dela träden i tre klasser:

I Friska träd
II Träd med friskt utseende, men med anatomiska symptom
III Träd med sjukt utseende (störningsträd).

Barranalyser av dessa tre klasser har visat, att halterna av makronäringsämnen i regel var högre hos de sjuka träden (klasserna II och III) än hos de friska (klass I). Beträffande mikronäringsämnen var situationen omvänd (Raitio och Rantala 1977). Härmed stödde alltså barranalyserna hypotesen om mikronäringsbristen.

Motsvarande symptom hos en hel del andra växter (även tallarter) har beskrivits som symptom på brist av mikronäringsämnen (t ex. Anderssen 1932, Hoagland et. al. 1935, Kessel och Stoate 1936, Chandler 1937, Piper 1942, Benzian och Warren 1956, Vail et. al. 1957, 1961, Bussler 1964, Stone och Will 1965, de Lanuza 1966, Oldercamp och Smilde 1966, Stone 1968, Rahimi och Bussler 1973).

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KELLOMÄKI, SEPPO O.D.C. 907.2

1977. Deterioration of forest ground cover during trampling. — SILVA FENNICA Vol. 11, N:o 3, 9 p. Helsinki.

The aim of the present study is to investigate the trampling tolerance of forest ground cover of the *Calluna*, *Vaccinium* and *Myrtillus* site types. Positive correlation was found between the site fertility and trampling tolerance of plant communities. Annual trampling at a level of about 16 000 visits per hectare decreased the biomass of the ground cover to almost half the original amount, and annual trampling of about 160 000 visits per hectare completely destroyed the forest ground cover irrespective of site fertility. Comparisons made between herb and grass dominated and forest ground cover showed that herb and grass cover is in the long run the best alternative for the management of ground cover in intensively used recreation areas.

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SAASTAMOINEN, OLLI O.D.C. 64: 89 + 907.2

1977. Economics of forest uses in Finnish Lapland. SILVA FENNICA Vol. 11, No. 3, 7 p. Helsinki.

The object of the study is to give a tentative indication of the realized economic significance of the principal forest (forestry land) uses in Finnish Lapland. Data concern the years of the 1970's. Nowadays timber harvesting generates a major part of the total value of production. Recreation (tourism) is in second place. Reindeer husbandry, collection of berries and mushrooms and hunting together produce, in the best years, an output value which is about one fifth of that of timber harvesting. Non-timber uses together produce a rather significant portion on the total value of the integrated forestry output.

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MÄKELÄ, MARKKU O.D.C. 525: 815.33/4

1977. The amount of logging residues and stump and root wood technically harvestable in South-east Finland. SILVA FENNICA Vol. 11, No. 3, 15 p. Helsinki.

The amounts of harvestable logging residues and stump- and root wood were examined in the area were 100 000 solid cu.m. of stemwood was cut in 1975. The cutting amounts of stemwood from work sites suitable for harvesting of logging residues was 35 000 m^3 and suitable for harvesting of stump- and root wood 38 000 m^3. The increase in the yield of wood (without bark) from logging residues compared with the unbarked stemwood was 2,4 %. The same percentage of wood from stump- and root wood was 5,0 . . . 5,8 % depending on the harvesting loss.

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LEHTONEN, IRJA O.D.C. 181.34

1977. Nutrient cycle in a pine stand: III Variation in nutrient content of soil, vegetation, and precipitation — SILVA FENNICA Vol. 11, No. 3, 11 p. Helsinki.

The study is part of a project designed to elucidate the nutrient budget of a Scots pine stand. Results of variations in the nutrient contents were compared with those obtained for the previous growing season.
The potassium and calcium contents varied the greatest in the humus layer. However, in the bottom and field layer vegetation and needles the variation in the nitrogen content was the greatest. The nutrient contents of the needles were affected by the physiological stage of development, needle age and the position in the crown of the tree. The nutrient content of the rainfall increased in the order: free rainfall, throughfall, and stem flow.

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KÄRKKÄINEN, MATTI O.D.C. 945.4

1977. Editorial observations on scientific series in forestry. — SILVA FENNICA Vol. 11, No. 3, 6 p. Helsinki.

The paper describes the use of paper area in some scientific series concerned with forestry. The material consisted of 8 series, the total number of analyzed pages being 2942. — According to the results the use of paper area was more efficient in journals and other similar periodicals which include several scientific papers than in series published as separate issues. The main reason was the more efficient editorial make-up. The Finnish papers included less figures but more tables than foreign series. There were marked differences between series irrespective of the country of origin. The average figure area varied from 60 to 180 cm² between series, for example. According to the observations there are good possibilities for making more efficient use of the paper area available.

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SF-00170 Helsinki 17, Finland.

O.D.C. 181.34 + 237.4

1977. Nutrient cycle in tree stands — Nordic symposium — SILVA FENNICA Vol. 11, No. 3, 57 p. Helsinki.

The Nordic working group for forest fertilization arranged from the 29th August to 1st of September 1977, in Finland a symposium on the Nutrient cycle in tree stands. During the symposium the following papers were presented:

- A bioelement budget of an old Scots pine forest in central Sweden. L. Bringmark.
- Mobilization of plant nutrients in a Scots pine forest moor in central Sweden. H. Staaf and B. Berg.
- Accumulation of organic matter and nitrogen on sand dunes following sand fixation and planting of dwarf mountain pine (*Pinus mugo* var. *mughus* (Scop.) Zenari). J. Neckelmann.
- [The correlation between peatland site type and nutrient content of the surface peat] (Sw.). C. J. Westman.
- The changes in the amounts of inorganic nutrients of the soil after clearfelling. N. Nykvist.
- Plant nutrient balance in decoration greenery cultivation. H. Holstener-Jorgensen.
- The effect of forest fertilization on primary production and nutrient cycling in the forest ecosystem. A. Albrektsson, A. Aronsson and C. O. Tamm.
- [Changes in the humuslayer after forest fertilization] (Sw.) H. Nõmmik.
- [Balanced nutrient uptake and the requirement for forest fertilization in tree stands on peatlands poor in nutrients] (Sw.) F. H. Braekke.
- Effect of fertilization on nutrient contents in needles and litterfall of Scots pine on dwarf shrub pine swamp. E. Paavilainen.
- Micro-nutrient deficiencies cause growth disturbances in trees. O. Huikari.
- [Growth disturbances in Scots pine nutrient balance in soil and micro nutrient deficiencies] (Sw.). H. Raitio.

KIRJOITUSTEN LAATIMISOHJEET

Silva Fennica-sarjassa julkaistaan lyhyitä metsätieteellisiä tutkimuksia ja kirjoituksia kotimaisilla kielillä tai jollakin suurella tieteellisellä kielellä. Julkaistavaksi tarkoitettu käsikirjoitus on jätettävä Seuran sihteerille painatuskelpoisessa asussa. Seuran hallitus ratkaisee asiantuntijoita kuultuaan, hyväksytäänkö kirjoitus painettavaksi.

Kirjoitusten laadinnassa noudatetaan Silva Fennican numerossa Vol. 4, 1970, N:o 3 painettuja kansainvälisiä ohjeita. Suureissa, yksiköissä sekä symbolien ja kaavojen merkinnöissä noudatetaan ohjeita, jotka ovat suomalaisissa standardeissa SFS 2300, 3100 ja 3101. Oikoluvussa noudatetaan standardia SFS 2324.

Kirjoituksen alkuun tulee julkaisun kielellä lyhyt yhdistelmä tutkimuksen tuloksista. Samoin laaditaan tutkimuksen yhteyteen lyhyt englanninkielinen tiivistelmä, jonka lisäksi kunkin Silvan numeron loppuun painetaan irti leikattavan kortin muotoon kustakin tutkimuksesta englanninkielinen esittely. Sisällysluetteloa ei käytetä. Mahdolliset kiitokset esitetään lyhyesti johdannan lopussa ja merkitään painettavaksi petiitillä.

Kuvien ja piirrosten viivapaksuudet ja tekstikoko on valittava siten, että ne sallivat painatuksen vaatiman pienennyksen. Kuvien ja piirrosten painatuskoosta on syytä neuvotella etukäteen toimittajan kanssa, sillä tarpeettomia kustannuksia aiheuttavaa painatuskokoa ei sallita. Valokuvien tulee olla teknisesti moitteettomia ja kiiltävälle valkealle paperille suurennettuja. Värikuvia ei yleensä hyväksytä painettavaksi. Kuvat ja taulukot numeroidaan kummatkin erikseen juoksevasti, ja niiden otsikoista laaditaan erillinen luettelo kirjapainoa varten.

Jos vieraskielisessä lyhennelmässä viitataan tiettyihin kuviin ja taulukoihin, on nämä varustettava vieraskielisin otsikoin ja selityksin. Muut kuvat ja taulukot voivat olla yksikielisiä.

Lähdeviittauksissa tekijännimet sijapäätteineen kirjoitetaan isoin kirjaimin mikäli tekijännimen vartalo on muuttunut. Muutoin taivutuspääte kirjoitetaan pienaakkosin. Esimerkkejä: KOSKISEN (1972) tutkimus . . ., YLI-VAKKURin (1972) tutkimus . . . Milloin tekijöitä on kolme tai useampia, mainitaan tekstissä vain ensimmäinen (esim. HEIKURAINEN ym. 1961). Vieraskielisessä tekstissä ym. korvataan merkinnällä et at. Jos julkaisulla on kaksi tekijää viitteessä, pannaan tekijöiden nimien väliin ja-sana painatuskielellä. Esimerkki: KELTIKANGAS ja SEPPÄLÄ (1973, s. 222) osoittivat . . .

Viitekirjallisuusluetteloidaan tekijännimien (kirjoitetaan isoin kirjaimin) mukaisessa aakkosjärjestyksessä. Jos tekijöitä on useampia, nimet erotetaan pilkulla, paitsi kaksi viimeistä, jotka erotetaan &-merkillä. Tekijän etunimistä suositellaan käytettäväksi vain alkukirjaimia. Tutkimusten nimet kirjoitetaan lyhentämättä. Julkaisusarjoista käytetään niitä lyhenteitä, jotka on painettu Silva Fennican numerossa Vol. 5, 1971, N:o 2. Täydellisempi luettelo on nähtävissä Seuran toimistossa. Kirjoituksen löytämisen helpottamiseksi mainitaan aikakauslehdistä myös sivunumerot. Suomenkielisistä tutkimuksista otetaan mukaan vieraskielisen lyhennelmän nimi. Volyymi merkitään julkaisusarjan nimen jälkeen. Jos kyseessä on aikakauslehti tai vastaava, numero merkitään volyymin jälkeen suluissa. Sivunumerot erotetaan kaksoispisteellä volyymistä tai suluissa olevasta numerosta. Jos samalla kertaa ilmestynyt volyymi sisältää useita tutkimuksia, merkinnässä sovelletaan ko. julkaisussa noudatettua tapaa. Esimerkkejä:

ILVESSALO, Y. 1952. Metsikön kasvun ja poistuman välisestä suhteesta. Summary: On the relation between growth and removal in forest stands. — Commun. Inst. For. Fenn. 40.1.

WILCOX, W. W., PONG, W. Y. & PARMETER, J. R. 1973. Effects of mistletoe and other defects on lumber quality in white fir. Wood & Fiber 4 (4): 272—277.

Englanninkielisen lyhennelmän ja mahdollisten kuva- ja taulukkotekstien käännättämisestä ja pätevän kieliasiantuntijan tekemästä tarkastamisesta huolehtii kirjoittaja. Seura voi maksaa kustannukset valtiovarainministeriön antamien ohjeiden mukaan. Jos kääntäjän lasku on ohjeiden edellyttämää tasoa korkeampi, kirjoittaja vastaa ylittävästä osuudesta. Lähempiä tietoja antaa Seuran julkaisujen toimittaja.

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